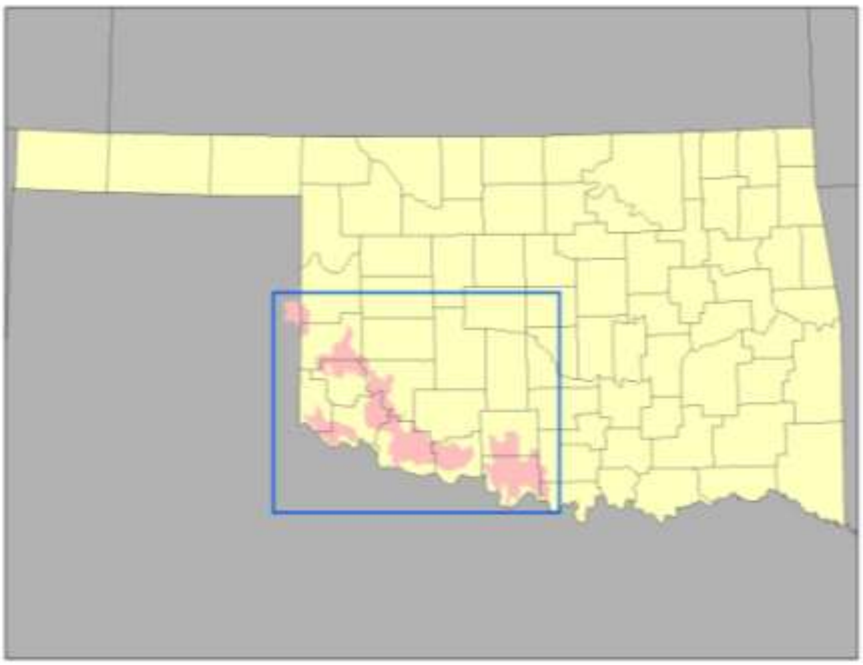
FINAL

BACTERIA AND TURBIDITY TOTAL MAXIMUM DAILY LOADS FOR THE RED RIVER, OKLAHOMA (OK311100, OK311200, OK311300, OK311310, OK311500, OK311510, OK311600, OK311800)



Prepared for:

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

Prepared by:

PARSONS

AUGUST 2010

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OKWBID

OK311100010290, OK311100010300, OK311100040010, OK311100040080, OK311200000030, OK311200000060, OK311200000080, OK311300010020, OK311310010070, OK311310020010, OK311310030010, OK311310030040, OK311310030050, OK311500010020, OK311500010050, OK311500010080, OK311500030010, OK311510010010, OK311510020120, OK311600010020, OK311600010040, OK311800000040, OK311800000070

Prepared for:

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TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

AEMS	Agricultural Environmental Management Service
ASAE	American Society of Agricultural Engineers
BMP	best management practice
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
cfs	Cubic feet per second
cfu	Colony-forming unit
CPP	Continuing planning process
CWA	Clean Water Act
DMR	Discharge monitoring report
HUC	Hydrologic unit code
IQR	Interquartile range
LA	Load allocation
LDC	Load duration curve
LOC	Line of organic correlation
mg	Million gallons
mgd	Million gallons per day
mg/L	Milligram per liter
mL	Milliliter
MOS	Margin of safety
MS4	Municipal separate storm sewer system
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NRMSE	Normalized root mean square error
NTU	Nephelometric turbidity unit
OLS	Ordinary least square
O.S.	Oklahoma statutes
ODAFF	Oklahoma Department of Agriculture, Food and Forestry
ODEQ	Oklahoma Department of Environmental Quality
OPDES	Oklahoma Pollutant Discharge Elimination System
OSWD	Onsite wastewater disposal
OWRB	Oklahoma Water Resources Board
PBCR	Primary body contact recreation
PRG	Percent reduction goal
RMSE	Root mean square error
SH	State Highway
SSO	Sanitary sewer overflow

TMDL	Total maximum daily load
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WLA	Wasteload allocation
WQM	Water quality monitoring
WQS	Water quality standard
WWTP	Wastewater treatment plant

Executive Summary

This report documents the data and assessment used to establish TMDLs for the pathogen indicator bacteria [fecal coliform, *Escherichia coli (E. coli)*, Enterococci] and turbidity for certain waterbodies in the Red River basin. Elevated levels of pathogen indicator bacteria in aquatic environments indicate that a waterbody is contaminated with human or animal feces and that a potential health risk exists for individuals exposed to the water. Elevated turbidity levels caused by excessive sediment loading and stream bank erosion impact aquatic communities. Data assessment and total maximum daily load (TMDL) calculations are conducted in accordance with requirements of Section 303(d) of the Clean Water Act (CWA), Water Quality Planning and Management Regulations (40 CFR Part 130), U.S. Environmental Protection Agency (USEPA) guidance, and Oklahoma Department of Environmental Quality (ODEQ) guidance and procedures. ODEQ is required to submit all TMDLs to USEPA for review and approval. Once the USEPA approves a TMDL, then the waterbody may be moved to Category 4a of a state's Integrated Water Quality Monitoring and Assessment Report, where it remains until compliance with water quality standards (WQS) is achieved (USEPA 2003).

The purpose of this TMDL report is to establish pollutant load allocations for indicator bacteria and turbidity in impaired waterbodies, which is the first step toward restoring water quality and protecting public health. TMDLs determine the pollutant loading a waterbody can assimilate without exceeding the WQS for that pollutant. TMDLs also establish the pollutant load allocation necessary to meet the WQS established for a waterbody based on the relationship between pollutant sources and instream water quality conditions. A TMDL consists of a wasteload allocation (WLA), load allocation (LA), and a margin of safety (MOS). The WLA is the fraction of the total pollutant load apportioned to point sources, and includes stormwater discharges regulated under the National Pollutant Discharge Elimination System (NPDES) as point sources. The LA is the fraction of the total pollutant load apportioned to nonpoint sources. The MOS is a percentage of the TMDL set aside to account for the lack of knowledge associated with natural process in aquatic systems, model assumptions, and data limitations.

This report does not stipulate specific control actions (regulatory controls) or management measures (voluntary best management practices) necessary to reduce bacteria or turbidity within each watershed. Watershed-specific control actions and management measures will be identified, selected, and implemented under a separate process.

E.1 Problem Identification and Water Quality Target

This TMDL report focuses on waterbodies in the Red River Basin, identified in Table ES-1, that ODEQ placed in Category 5 [303(d) list] of the *Water Quality in Oklahoma, 2008 Integrated Report* (2008 Integrated Report) for nonsupport of primary body contact recreation (PBCR) or warm water aquatic community (WWAC).

Elevated levels of bacteria or turbidity above the WQS result in the requirement that a TMDL be developed. The TMDLs established in this report are a necessary step in the process to develop the pollutant loading controls needed to restore the primary body contact recreation or fish and wildlife propagation use designated for each waterbody.

Table ES-1 Excerpt from the 2008 Integrated Report – Oklahoma 303(d) List of Impaired Waters (Category 5)

Waterbody ID	Waterbody Name	Stream Miles	TMDL Date	Priority	ENT	*E. coli*	FC	Designated Use Primary Body Contact Recreation	Turbidity	Designated Use Warm Water Aquatic Life
OK311800000070_00	Deer Creek	22.21	2019	4					X	N
OK311800000040_00	Haystack Creek	43.06	2016	3	X	X		N	X	N
OK311600010040_00	Sandy Creek (Lebos)	39.65	2013	2					X	N
OK311600010020_00	Gypsum Creek	28.1	2016	3	X			N	X	N
OK311510020120_00	Sweetwater Creek	16.43	2019	4	X	X		N	X	N
OK311510010010_10	North Fork of the Red River, SH 34, Carter	47.29	2019	4	X			N	X	N
OK311500030010_00	Elk Creek, SH 19, Roosevelt	15.7	2019	4					X	N
OK311500010080_00	Otter Creek	23.13	2010	1	X	X		N	X	N
OK311500010050_00	Stinking Creek	17.44	2016	3					X	N
OK311500010020_10	North Fork of the Red River, US 62, Headrick	61.7	2016	3					X	N
OK311310030050_00	Brush Creek	11.64	2016	3					X	N
OK311310030040_00	Little Deep Red Creek	33.57	2013	2					X	N
OK311310030010_00	Deep Red Creek	57.29	2016	3	X	X		N	X	N
OK311310020010_00	West Cache Creek, SH5B, Taylor	9.1	2019	4					X	N
OK311310010070_00	Suttle Creek	19.41	2019	4					X	N
OK311300010020_10	East Cache Creek, SH 53, Walters	17.11	2013	2					X	N
OK311300010020_00	Cache Creek, East	9.05	2013	2					X	N
OK311200000080_00	Dry Creek	20.96	2013	2	X	X	X	N	X	N
OK311200000060_00	Cow Creek	25.73	2013	2					X	N
OK311200000030_00	Beaver Creek	26.44	2010	1	X			N	X	N
OK311100040080_00	Mud Creek, West, Lower	27.81	2013	2					X	N

Waterbody ID	Waterbody Name	Stream Miles	TMDL Date	Priority	ENT	*E. coli*	FC	Designated Use Primary Body Contact Recreation	Turbidity	Designated Use Warm Water Aquatic Life
OK311100040010_00	Mud Creek	49.53	2013	2					**X**	**N**
OK311100010300_00	Fleetwood Creek	10.91	2019	4					**X**	**N**
OK311100010290_00	Red Creek	17.42	2016	3	**X**	**X**		**N**	**X**	**N**

ENT = enterococci; FC = fecal coliform
N = Not attaining; X = Criterion exceeded
Source: 2008 Integrated Report, ODEQ 2008.

Table ES-2 summarizes water quality data collected during primary contact recreation season from the water quality monitoring (WQM) stations between 2000 and 2009 for each bacterial indicator. The data summary in Table ES-2 provides a general understanding of the amount of water quality data available and the severity of exceedances of the water quality criteria. This data collected during the primary contact recreation season includes the data used to support the decision to place specific waterbodies within the Study Area on the ODEQ 2008 303(d) list (ODEQ 2008). It also includes the new date collected after the data cutoff date for the 2008 303(d) list.

Table ES-2 Summary of Indicator Bacteria Samples from Primary Body Contact Recreation Season, 2000-2009

Waterbody ID	Waterbody Name	Indicator	Number of samples	Geometric Mean Concentration (count/100 ml)	Number of samples exceeding single sample criterion	% samples exceeding single sample criterion	2008 303(d)	Notes
OK311800000040_00	Haystack Creek	EC	11	186	3	27%	X	TMDL required
		ENT	11	231	8	73%	X	TMDL required
OK311600010020_00	Gypsum Creek	EC	11	114	1	9%		Not Impaired
		ENT	11	205	8	73%	X	TMDL required
OK311510020120_00	Sweetwater Creek	EC	11	354	5	45%	X	TMDL required
		ENT	11	207	9	82%	X	TMDL required
OK311510010010_10	North Fork of the Red River, SH 34, Carter	EC	19	41	1	5%		Not Impaired
		ENT	19	34	3	16%	X	TMDL required
OK311500010080_00	Otter Creek	EC	11	178	3	27%	X	TMDL required
		ENT	11	159	7	64%	X	TMDL required
OK311310030010_00	Deep Red Creek	EC	11	304	4	36%	X	TMDL required
		ENT	11	325	9	82%	X	TMDL required
OK311200000080_00	Dry Creek	FC	6	456	2	33%	X	Delist: Insufficient number of samples
		EC	4	273	1	25%	X	Delist: Insufficient number of samples
		ENT	4	501	3	75%	X	Delist: Insufficient number of samples
OK311200000030_00	Beaver Creek	EC	10	111	3	30%		Not Impaired
		ENT	10	92	5	50%	X	TMDL required
OK311100010290_00	Red Creek	EC	10	173	5	50%	X	TMDL required
		ENT	10	209	6	60%	X	TMDL required

Fecal coliform (FC) water quality criterion = Geometric Mean of 400 counts/100 mL
E. coli (EC) water quality criterion = Geometric Mean of 126 counts/100 mL
Enterococci (ENT) water quality criterion = Geometric Mean of 33 counts/100 mL

The definition of PBCR is summarized by the following excerpt from Chapter 45 of the Oklahoma WQSs.

(a) Primary Body Contact Recreation involves direct body contact with the water where a possibility of ingestion exists. In these cases the water shall not contain chemical, physical or biological substances in concentrations that are irritating to skin or sense organs or are toxic or cause illness upon ingestion by human beings.

(b) In waters designated for Primary Body Contact Recreation...limits...shall apply only during the recreation period of May 1 to September 30. The criteria for Secondary Body Contact Recreation will apply during the remainder of the year.

To implement Oklahoma's WQS for PBCR, the Oklahoma Water Resources Board (OWRB) promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2008a). The abbreviated excerpt below from Chapter 46: 785:46-15-6, stipulates how water quality data will be assessed to determine support of the PBCR use as well as how the water quality target for TMDLs will be defined for each bacterial indicator.

(a) Scope. The provisions of this Section shall be used to determine whether the subcategory of Primary Body Contact of the beneficial use of Recreation designated in OAC 785:45 for a waterbody is supported during the recreation season from May 1 through September 30 each year. Where data exist for multiple bacterial indicators on the same waterbody or waterbody segment, the determination of use support shall be based upon the use and application of all applicable tests and data.

(b) Screening levels:

(1) The screening level for fecal coliform shall be a density of 400 colonies per 100 ml.

(2) The screening level for Escherichia coli shall be a density of 235 colonies per 100 ml in streams designated in OAC 785:45 as Scenic Rivers and in lakes, and 406 colonies per 100 ml in all other waters of the state designated as Primary Body Contact Recreation.

(3) The screening level for enterococci shall be a density of 61 colonies per 100 ml in streams designated in OAC 785:45 as Scenic Rivers and in lakes, and 108 colonies per 100 ml in all other waters of the state designated as Primary Body Contact Recreation.

(c) Fecal coliform:

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to fecal coliform if the geometric mean of 400 colonies per 100 ml is met and no greater than 25% of the sample concentrations from that waterbody exceed the screening level prescribed in (b) of this Section.

(d) Escherichia coli (E. coli):

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to E. coli if the geometric mean of 126 colonies per 100 ml is met, or the sample concentrations from that waterbody taken during the recreation season do not exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

(e) Enterococci:

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to enterococci if the geometric mean of 33 colonies per 100 ml is met, or the sample concentrations from that waterbody taken during the recreation season do not exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

Where concurrent data exist for multiple bacterial indicators on the same waterbody or waterbody segment, each indicator group must demonstrate compliance with the numeric criteria prescribed (OWRB 2008). Waterbodies placed on the 303(d) list for not supporting the PBCR are the result of individual samples exceeding the instantaneous criteria or the long-term geometric mean of individual samples exceeding the geometric mean criteria for each respective bacterial indicator. Targeting the instantaneous criterion established for the primary contact recreation season (May 1^{st} to September 30^{th}) as the water quality goal for TMDLs corresponds to the basis for 303(d) listing and may be protective of the geometric mean criterion as well as the criteria for the secondary contact recreation season. However, both the instantaneous and geometric mean criteria for *E. coli* and Enterococci will be evaluated as water quality targets to ensure the most protective goal is established for each waterbody.

All TMDLs for fecal coliform must take into account that no more than 25 percent of the samples may exceed the instantaneous numeric criteria. For *E. coli* and Enterococci, no samples may exceed instantaneous criteria. Since the attainability of stream beneficial uses for *E. coli* and Enterococci is based on the compliance of either the instantaneous or a long-term geometric mean criterion, percent reductions goals will be calculated for both criteria. TMDLs will be based on the percent reduction required to meet either the instantaneous or the long-term geometric mean criterion, whichever is less.

Turbidity is a measure of water clarity and is caused by suspended particles in the water column. Because turbidity cannot be expressed as a mass load, total suspended solids (TSS) are used as a surrogate for the TMDLs in this report. Therefore, both turbidity and TSS data are presented.

Table ES-3 summarizes a subset of water quality data collected from the WQM stations between 1998 and 2009 for turbidity under base flow conditions, which ODEQ considers to be all flows less than the 25^{th} flow exceedance percentile (i.e., the lower 75 percent of flows) Water quality samples collected under flow conditions greater than the 25^{th} flow exceedance percentile (highest flows) were therefore excluded from the data set used for TMDL analysis. Table ES-4 presents a subset of data for TSS samples collected during base flow conditions.

Table ES-3 Summary of Turbidity Samples Collected During Base Flow Conditions, 1998-2009

Waterbody ID	Waterbody Name	WQM Stations	Number of turbidity samples	Number of samples greater than 50 NTU	% samples exceeding criterion	Average Turbidity (NTU)
OK311800000070_00	Deer Creek	OK311800000070C	19	7	37%	52
OK311800000040_00	Haystack Creek	OK311800-00-0040D	20	7	35%	134
OK311600010040_00	Sandy Creek (Lebos)	OK311600010040-001AT,SWQ3	117	49	42%	72
OK311600010020_00	Gypsum Creek	21-4-1	19	5	26%	98
OK311510020120_00	Sweetwater Creek	311510020120-03	19	3	16%	42
OK311510010010_10	North Fork of the Red River, SH 34, Carter	311510010010-001AT	68	5	7%	25
OK311500030010_00	Elk Creek, SH 19, Roosevelt	OK311500030010-001AT,W84ELEC09	150	63	42%	130
OK311500010080_00	Otter Creek	OK311500-01-0080F	17	6	35%	107
OK311500010050_00	Stinking Creek	OK311500010050G	20	8	40%	66
OK311500010020_10	North Fork of the Red River, US 62, Headrick	OK311500010020-001AT	113	17	15%	76
OK311310030050_00	Brush Creek	OK311310030050G	14	7	50%	117
OK311310030040_00	Little Deep Red Creek	OK311310-03-0040D	17	5	29%	119
OK311310030010_00	Deep Red Creek	OK311310-03-0010D	16	10	63%	122
OK311310020010_00	West Cache Creek, SH5B, Taylor	OK311310020010-001AT,OK311310-02-0010M	66	14	21%	47
OK311310010070_00	Suttle Creek	400265	12	7	58%	115
OK311300010020_10	East Cache Creek, SH 53, Walters	11300010020-001AT	64	27	42%	51
OK311300010020_00	Cache Creek, East	OK311300010020-001AT,OKS0104	17	10	59%	75
OK311200000080_00	Dry Creek	OK311200000080G	17	5	29%	94
OK311200000060_00	Cow Creek	OK311200-00-0060L	43	25	58%	99
OK311200000030_00	Beaver Creek	311200000060-01,OK311200-00-0030L	16	7	44%	69
OK311100040080_00	Mud Creek, Lower West	OK311100040080G	20	18	90%	222
OK311100040010_00	Mud Creek	OK311100040010-001AT,OK311100-04-0010D	77	54	70%	132
OK311100010300_00	Fleetwood Creek	OK311100-01-0300D	14	6	43%	135
OK311100010290_00	Red Creek	OK311100-01-0290D	20	9	45%	249

Table ES-4 Summary of TSS Samples During Base Flow Conditions, 1998-2009

Waterbody ID	Waterbody Name	WQM Stations	Number of TSS samples	Average TSS (mg/L)
OK311800000070_00	Deer Creek	OK311800000070C	18	51
OK311800000040_00	Haystack Creek	OK311800-00-0040D	20	293
OK311600010040_00	Sandy Creek (Lebos)	OK311600010040-001AT,SWQ3	43	64
OK311600010020_00	Gypsum Creek	21-4-1	19	94
OK311510020120_00	Sweetwater Creek	311510020120-03	18	60
OK311510010010_10	North Fork of the Red River, SH 34, Carter	311510010010-001AT	13	27
OK311500030010_00	Elk Creek, SH 19, Roosevelt	OK311500030010-001AT,W84ELEC09	39	156
OK311500010080_00	Otter Creek	OK311500-01-0080F	16	52
OK311500010050_00	Stinking Creek	OK311500010050G	19	80
OK311500010020_10	North Fork of the Red River, US 62, Headrick	OK311500010020-001AT	19	73
OK311310030050_00	Brush Creek	OK311310030050G	14	98
OK311310030040_00	Little Deep Red Creek	OK311310-03-0040D	17	81
OK311310030010_00	Deep Red Creek	OK311310-03-0010D	15	56
OK311310020010_00	West Cache Creek, SH5B, Taylor	OK311310020010-001AT,OK311310-02-0010M	20	55
OK311310010070_00	Suttle Creek	400265	12	65
OK311300010020_10	East Cache Creek, SH 53, Walters	11300010020-001AT	13	50
OK311300010020_00	Cache Creek, East	OK311300010020-001AT,OKS0104	17	69
OK311200000080_00	Dry Creek	OK311200000080G	16	35
OK311200000060_00	Cow Creek	OK311200-00-0060L	29	69
OK311200000030_00	Beaver Creek	311200000060-01,OK311200-00-0030L	15	52
OK311100040080_00	Mud Creek, Lower West	OK311100040080G	18	94
OK311100040010_00	Mud Creek	OK311100040010-001AT,OK311100-04-0010D	22	82
OK311100010300_00	Fleetwood Creek	OK311100-01-0300D	15	59
OK311100010290_00	Red Creek	OK311100-01-0290D	21	128

The beneficial use of WWAC is one of several subcategories of the Fish and Wildlife Propagation use established to manage the variety of communities of fish and shellfish throughout the state (OWRB 2008). The numeric criteria for turbidity to maintain and protect the use of “Fish and Wildlife Propagation” from Title 785:45-5-12 (f) (7) is as follows:

(A) Turbidity from other than natural sources shall be restricted to not exceed the following numerical limits:

1. Cool Water Aquatic Community/Trout Fisheries: 10 NTUs;

2. Lakes: 25 NTU; and

3. Other surface waters: 50 NTUs.

(B) In waters where background turbidity exceeds these values, turbidity from point sources will be restricted to not exceed ambient levels.

(C) Numerical criteria listed in (A) of this paragraph apply only to seasonal base flow conditions.

(D) Elevated turbidity levels may be expected during, and for several days after, a runoff event.

The abbreviated excerpt below from Chapter 46: 785:46-15-5, stipulates how water quality data will be assessed to determine support of fish and wildlife propagation as well as how the water quality target for TMDLs will be defined for turbidity.

Assessment of Fish and Wildlife Propagation support

(a) Scope. The provisions of this Section shall be used to determine whether the beneficial use of Fish and Wildlife Propagation or any subcategory thereof designated in OAC 785:45 for a waterbody is supported.

(e) Turbidity. The criteria for turbidity stated in 785:45-5-12(f)(7) shall constitute the screening levels for turbidity. The tests for use support shall follow the default protocol in 785:46-15-4(b).

785:46-15-4. Default protocols

(b) Short term average numerical parameters.

(1) Short term average numerical parameters are based upon exposure periods of less than seven days. Short term average parameters to which this Section applies include, but are not limited to, sample standards and turbidity.

(2) A beneficial use shall be deemed to be fully supported for a given parameter whose criterion is based upon a short term average if 10% or less of the samples for that parameter exceed the applicable screening level prescribed in this Subchapter.

TMDLs for turbidity in streams designated as WWAC must take into account that no more than 10 percent of the samples may exceed the numeric criterion of 50 nephelometric turbidity units (NTU). However, as described above, because turbidity cannot be expressed as a mass load, TSS is used as a surrogate in this TMDL. Since there is no numeric criterion in the Oklahoma WQS for TSS, a regression method to convert the turbidity criterion to TSS based on a relationship between turbidity and TSS was used to establish TSS goals as surrogates. Table ES-5 provides the results of the waterbody specific regression analysis.

Table ES-5 Regression Statistics and TSS Goals

Waterbody ID	Waterbody Name	R-square	NRMSE	TSS Goals (mg/L)[a]
OK311800000070_00	Deer Creek	0.827	10.1%	46
OK311800000040_00	Haystack Creek	0.791	16.7%	48
OK311600010040_00	Sandy Creek (Lebos)	0.711	16.9%	101
OK311600010020_00	Gypsum Creek	0.958	7.3%	70
OK311510020120_00	Sweetwater Creek	0.923	6.5%	74
OK311510010010_10	North Fork of the Red River, SH 34, Carter	0.709	24.3%	112
OK311500030010_00	Elk Creek, SH 19, Roosevelt	0.815	13.0%	63
OK311500010080_00	Otter Creek	0.92	6.8%	41
OK311500010050_00	Stinking Creek	0.955	4.5%	68
OK311500010020_10	North Fork of the Red River, US 62, Headrick	0.75	10.6%	94
OK311310030050_00	Brush Creek	0.875	9.5%	53
OK311310030040_00	Little Deep Red Creek	0.789	16.8%	34
OK311310030010_00	Deep Red Creek	0.85	7.1%	32
OK311310020010_00	West Cache Creek, SH5B, Taylor	0.641	21.7%	59
OK311310010070_00	Suttle Creek	0.968	5.0%	46
OK311300010020_10	East Cache Creek, SH 53, Walters	0.798	13.3%	41
OK311300010020_00	Cache Creek, East	0.902	6.8%	40
OK311200000080_00	Dry Creek	0.815	26.8%	41
OK311200000060_00	Cow Creek	0.911	8.4%	41
OK311200000030_00	Beaver Creek	0.848	8.5%	36
OK311100040080_00	Mud Creek, Lower West	0.502	23.0%	16
OK311100040010_00	Mud Creek	0.889	6.4%	33
OK311100010300_00	Fleetwood Creek	0.958	6.4%	39
OK311100010290_00	Red Creek	0.974	6.8%	34

[a] WQ goal minus MOS

After re-evaluating bacteria and turbidity/TSS data for the streams listed in Table ES-1, bacteria impairments on Dry Creek are recommended for delisting and bacteria TMDLs are not required for Dry Creek. Table ES-6 shows the bacteria and turbidity TMDLs that will be developed in this report:

Table ES-6 Stream Segments and Pollutants for TMDL Development

Waterbody ID	Waterbody Name	Stream Miles	TMDL Date	Priority	ENT	*E. coli*	Turbidity
OK311800000070_00	Deer Creek	22.21	2019	4			X
OK311800000040_00	Haystack Creek	43.06	2016	3	X	X	X
OK311600010040_00	Sandy Creek (Lebos)	39.65	2013	2			X
OK311600010020_00	Gypsum Creek	28.1	2016	3	X		X
OK311510020120_00	Sweetwater Creek	16.43	2019	4	X	X	X
OK311510010010_10	North Fork of the Red River, SH 34, Carter	47.29	2019	4	X		X
OK311500030010_00	Elk Creek, SH 19, Roosevelt	15.7	2019	4			X
OK311500010080_00	Otter Creek	23.13	2010	1	X	X	X
OK311500010050_00	Stinking Creek	17.44	2016	3			X
OK311500010020_10	North Fork of the Red River, US 62, Headrick	61.7	2016	3			X
OK311310030050_00	Brush Creek	11.64	2016	3			X
OK311310030040_00	Little Deep Red Creek	33.57	2013	2			X
OK311310030010_00	Deep Red Creek	57.29	2016	3	X	X	X
OK311310020010_00	West Cache Creek, SH5B, Taylor	9.1	2019	4			X
OK311310010070_00	Suttle Creek	19.41	2019	4			X
OK311300010020_10	East Cache Creek, SH 53, Walters	17.11	2013	2			X
OK311300010020_00	Cache Creek, East	9.05	2013	2			X
OK311200000080_00	Dry Creek	20.96	2013	2			X
OK311200000060_00	Cow Creek	25.73	2013	2			X
OK311200000030_00	Beaver Creek	26.44	2010	1	X		X
OK311100040080_00	Mud Creek, West, Lower	27.81	2013	2			X
OK311100040010_00	Mud Creek	49.53	2013	2			X
OK311100010300_00	Fleetwood Creek	10.91	2019	4			X
OK311100010290_00	Red Creek	17.42	2016	3	X	X	X

E.2 Pollutant Source Assessment

A pollutant source assessment characterizes known and suspected sources of pollutant loading to impaired waterbodies. Sources within a watershed are categorized and quantified to the extent that information is available. Bacteria originate from warm-blooded animals; some plant life and sources may be point or nonpoint in nature. Turbidity may originate from NPDES-permitted facilities, fields, construction sites, quarries, stormwater runoff and eroding stream banks.

Point sources are permitted through the NPDES program. NPDES-permitted facilities that discharge treated wastewater are required to monitor for one of the three bacterial indicators (fecal coliform, *E coli*, or Enterococci) and TSS in accordance with their permits. Nonpoint sources are diffuse sources that typically cannot be identified as entering a waterbody through a discrete conveyance at a single location. Nonpoint sources may emanate from land activities that contribute bacteria or TSS to surface water as a result of rainfall runoff. For the TMDLs in this report, all sources of pollutant loading not regulated by NPDES are considered nonpoint sources. Sediment loading of streams can originate from natural erosion processes, including the weathering of soil, rocks, and uncultivated land; geological abrasion; and other natural phenomena. There is insufficient data available to quantify contributions of TSS from these natural processes. TSS or sediment loading can also occur under non-runoff conditions as a result of anthropogenic activities in riparian corridors which cause erosive conditions. Given the lack of data to establish the background conditions for TSS/turbidity, separating background loading from nonpoint sources whether it is from natural or anthropogenic processes is not feasible in this TMDL development. Table ES-7 summarizes the point and nonpoint sources that contribute bacteria or TSS to each respective waterbody.

Table ES-7 Summary of Potential Pollutant Sources by Category

Waterbody ID	Waterbody Name	Municipal NPDES Facility	Industrial NPDES Facility	MS4	NPDES No Discharge Facility	CAFO	Mines	Construction Stormwater Permit	Nonpoint Source
OK311800000070_00	Deer Creek								TSS
OK311800000040_00	Haystack Creek								Bacteria, TSS
OK311600010040_00	Sandy Creek (Lebos)								TSS
OK311600010020_00	Gypsum Creek						TSS		Bacteria, TSS
OK311510020120_00	Sweetwater Creek						TSS		Bacteria, TSS
OK311510010010_10	North Fork of the Red River, SH 34, Carter	Bacteria					TSS		TSS
OK311500030010_00	Elk Creek, SH 19, Roosevelt						TSS		TSS
OK311500010080_00	Otter Creek		TSS		Bacteria		TSS		Bacteria, TSS
OK311500010050_00	Stinking Creek						TSS		TSS
OK311500010020_10	North Fork of the Red River, US 62, Headrick				Bacteria		TSS		Bacteria, TSS
OK311310030050_00	Brush Creek								TSS
OK311310030040_00	Little Deep Red Creek								TSS
OK311310030010_00	Deep Red Creek					Bacteria	TSS		Bacteria, TSS
OK311310020010_00	West Cache Creek, SH5B, Taylor						TSS		TSS
OK311310010070_00	Suttle Creek								TSS

Waterbody ID	Waterbody Name	Municipal NPDES Facility	Industrial NPDES Facility	MS4	NPDES No Discharge Facility	CAFO	Mines	Construction Stormwater Permit	Nonpoint Source
OK311300010020_10	East Cache Creek, SH 53, Walters								TSS
OK311300010020_00	Cache Creek, East								TSS
OK311200000080_00	Dry Creek						TSS		TSS
OK311200000060_00	Cow Creek						TSS		TSS
OK311200000030_00	Beaver Creek				Bacteria	Bacteria			Bacteria, TSS
OK311100040080_00	Mud Creek, West, Lower								TSS
OK311100040010_00	Mud Creek		TSS						TSS
OK311100010300_00	Fleetwood Creek								TSS
OK311100010290_00	Red Creek								Bacteria, TSS

No facility present in watershed.

Facility present in watershed, but not recognized as pollutant source.

E.3 Using Load Duration Curves to Develop TMDLs

The TMDL calculations presented in this report are derived from load duration curves (LDC). LDCs facilitate rapid development of TMDLs, and as a TMDL development tool are effective at identifying whether impairments are associated with point or nonpoint sources. The technical approach for using LDCs for TMDL development includes the following steps:

Preparing flow duration curves for gaged and ungaged WQM stations;

Estimating existing loading in the waterbody using ambient bacteria water quality data; and estimating loading in the waterbody using measured TSS water quality data and turbidity-converted data; and

Using LDCs to identify the critical condition that will dictate loading reductions and the overall percent reduction goal (PRG) necessary to attain WQS.

Use of the LDC obviates the need to determine a design storm or selected flow recurrence interval with which to characterize the appropriate flow level for the assessment of critical conditions. For waterbodies impacted by both point and nonpoint sources, the “nonpoint source critical condition” would typically occur during high flows, when rainfall runoff would contribute the bulk of the pollutant load, while the “point source critical condition” would typically occur during low flows, when wastewater treatment plant (WWTP) effluents would dominate the base flow of the impaired water. However, flow range is only a general indicator of the relative proportion of point/nonpoint contributions. Violations have been noted under low flow conditions in some watersheds that contain no point sources.

LDCs display the maximum allowable load over the complete range of flow conditions by a line using the calculation of flow multiplied by a water quality criterion. The TMDL can be expressed as a continuous function of flow, equal to the line, or as a discrete value derived from a specific flow condition.

The basic steps to generating an LDC involve:

- obtaining daily flow data for the site of interest from the U.S. Geological Survey (USGS);
- sorting the flow data and calculating flow exceedance percentiles for the time period and season of interest;
- obtaining the water quality data from the primary contact recreation season (May 1 through September 30); or obtaining available turbidity and TSS water quality data;
- matching the water quality observations with the flow data from the same date;
- displaying a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQS for each respective bacteria indicator; or displaying a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQ_{goal} for TSS;
- converting measured concentration values to loads by multiplying the flow at the time the sample was collected by the water quality parameter concentration (for sampling events with both TSS and turbidity data, the measured TSS value is used; if only turbidity was measured, the value was converted to TSS using the regression equation in Figure 4-1 through Figure 4-3); or multiplying the flow by the bacteria indicator concentration to calculate daily loads; then

- plotting the flow exceedance percentiles and daily load observations in a load duration plot.

For bacteria TMDLs the culmination of these steps is expressed in the following formula, which is displayed on the LDC as the TMDL curve:

TMDL (cfu/day) = WQS * flow (cfs) * unit conversion factor

Where: WQS = 400 cfu /100 mL (Fecal coliform); 406 cfu/100 mL (E. coli); or 108 cfu/100 mL (Enterococci)

unit conversion factor = 24,465,525 mL*s / ft3*day

For turbidity (TSS) TMDLs the culmination of these steps is expressed in the following formula, which is displayed on the LDC as the TMDL curve:

TMDL (lb/day) = WQ_{goal}* flow (cfs) * unit conversion factor

where: WQ_{goal} = waterbody specific TSS concentration derived from regression analysis results presented in Table 4-1

unit conversion factor = 5.39377 L*s*lb /(ft^3*day*mg)

Historical observations of bacteria, TSS and/or turbidity concentrations are paired with flow data and are plotted as separate LDCs. The fecal coliform load (or the y-value of each point) is calculated by multiplying the fecal coliform concentration (colonies/100 mL) by the instantaneous flow (cubic feet per second) at the same site and time, with appropriate volumetric and time unit conversions. Fecal coliform/*E. coli*/Enterococci loads representing exceedance of water quality criteria fall above the water quality criterion line. Likewise, the TSS load (or the y-value of each point) is calculated by multiplying the TSS concentration (measured or converted from turbidity) (mg/L) by the instantaneous flow (cfs) at the same site and time, with appropriate volumetric and time unit conversions. TSS loads representing exceedance of water quality criteria fall above the TMDL line.

E.4 TMDL Calculations

A TMDL is expressed as the sum of all WLAs (point source loads), LAs (nonpoint source loads), and an appropriate MOS, which attempts to account for the lack of knowledge concerning the relationship between effluent limitations and water quality.

This definition can be expressed by the following equation:

$$TMDL = \Sigma\ WLA + \Sigma\ LA + MOS$$

For each waterbody the TMDLs presented in this report are expressed as a percent reduction across the full range of flow conditions. The difference between existing loading and the water quality target is used to calculate the loading reductions required. PRG are calculated for each waterbody and bacterial indicator species as the reductions in load required so no existing instantaneous water quality observations would exceed the water quality target for *E. coli* and Enterococci and no more than 25 percent of the samples exceed the water quality target for fecal coliform.

Table ES-8 presents the percent reductions necessary for each bacterial indicator causing nonsupport of the PBCR use in each waterbody of the Study Area. Selection of the appropriate PRG for each waterbody in Table ES-8 is denoted by bold text. The TMDL PRG will be the lesser of that required to meet the geometric mean or instantaneous criteria for *E. coli* and

Enterococci because WQSs are considered to be met if, 1) either the geometric mean of all data is less than the geometric mean criteria, or 2) no samples exceed the instantaneous criteria. The PRGs range from 21 to 99 percent.

Table ES-8 TMDL Percent Reductions Required to Meet Water Quality Standards for Indicator Bacteria

Waterbody ID	Waterbody Name	Required Reduction Rate				
		FC	EC		ENT	
		Instant-aneous	Instant-aneous	Geo-mean	Instant-aneous	Geo-mean
OK311800000040_00	Haystack Creek		83%	**39%**	98%	**87%**
OK311600010020_00	Gypsum Creek				87%	**86%**
OK311510020120_00	Sweetwater Creek		**64%**	68%	**77%**	86%
OK311510010010_10	North Fork of the Red River, SH 34, Carter				96%	**13%**
OK311500010080_00	Otter Creek		82%	**36%**	96%	**81%**
OK311310030010_00	Deep Red Creek		97%	**36%**	99%	**81%**
OK311200000030_00	Beaver Creek				93%	**68%**
OK311100010290_00	Red Creek		93%	**34%**	99%	**86%**

Similarly, percent reduction goals for TSS are calculated as the required overall reduction so that no more than 10 percent of the samples exceed the water quality target for TSS. The PRGs for the fourteen waterbodies included in this TMDL report are summarized in Table ES-9 and range from 6 to 95 percent.

Table ES-9 TMDL Percent Reductions Required to Meet Water Quality Targets for Total Suspended Solids

Waterbody ID	Waterbody Name	Required Reduction Rate
OK311800000070_00	Deer Creek	60%
OK311800000040_00	Haystack Creek	50%
OK311600010040_00	Sandy Creek (Lebos)	67%
OK311600010020_00	Gypsum Creek	58%
OK311510020120_00	Sweetwater Creek	36%
OK311510010010_10	North Fork of the Red River, SH 34, Carter	6%
OK311500030010_00	Elk Creek, SH 19, Roosevelt	86%
OK311500010080_00	Otter Creek	62%
OK311500010050_00	Stinking Creek	62%
OK311500010020_10	North Fork of the Red River, US 62, Headrick	40%
OK311310030050_00	Brush Creek	81%
OK311310030040_00	Little Deep Red Creek	76%
OK311310030010_00	Deep Red Creek	75%
OK311310020010_00	West Cache Creek, SH5B, Taylor	65%
OK311310010070_00	Suttle Creek	65%

Waterbody ID	Waterbody Name	Required Reduction Rate
OK311300010020_10	East Cache Creek, SH 53, Walters	62%
OK311300010020_00	Cache Creek, East	83%
OK311200000080_00	Dry Creek	75%
OK311200000060_00	Cow Creek	80%
OK311200000030_00	Beaver Creek	59%
OK311100040080_00	Mud Creek, Lower West	95%
OK311100040010_00	Mud Creek	88%
OK311100010300_00	Fleetwood Creek	77%
OK311100010290_00	Red Creek	94%

The TMDL, WLA, LA, and MOS vary with flow condition, and are calculated at every 5th flow interval percentile. The WLA component of each TMDL is the sum of all WLAs within each contributing watershed. The sum of the WLAs can be represented as a single line below the LDC. The LDC and the simple equation of:

Average LA = average TMDL – MOS - ∑WLA

can provide an individual value for the LA in counts per day, which represents the area under the TMDL target line and above the WLA line.

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs include an MOS and account for seasonal variability. The MOS, which can be implicit or explicit, is a conservative measure incorporated into the TMDL equation that accounts for the lack of knowledge associated with calculating the allowable pollutant loading to ensure WQSs are attained.

For bacteria TMDLs, an explicit MOS was set at 10 percent.

For turbidity, the TMDLs are calculated for TSS instead of turbidity. Thus, the quality of the regression has a direct impact on confidence of the TMDL calculations. The better the regression is, the more confidence there is in the TMDL targets. As a result, it leads to a smaller margin of safety. The selection of MOS is based on the normalized root mean square error (NRMSE) for each waterbody. The explicit MOS ranges from 10 percent to 25 percent. Table 5-4 shows the MOS for each waterbody.

The bacteria TMDLs established in this report adhere to the seasonal application of the Oklahoma WQS which limits the PBCR use to the period of May 1st through September 30th. Similarly, the TSS TMDLs established in this report adhere to the seasonal application of the Oklahoma WQS for turbidity, which applies to seasonal base flow conditions only. Seasonal variation was also accounted for in these TMDLs by using more than 5 years of water quality data and by using the longest period of USGS flow records when estimating flows to develop flow exceedance percentiles.

E.5 Reasonable Assurance

As authorized by Section 402 of the CWA, ODEQ has delegation of the NPDES in Oklahoma, except for certain jurisdictional areas related to agriculture and the oil and gas industry retained by the Oklahoma Department of Agriculture and Oklahoma Corporation Commission, for which the USEPA has retained permitting authority. The NPDES program in

Oklahoma is implemented via Title 252, Chapter 606 of the Oklahoma Pollution Discharge Elimination System (OPDES) Act, and in accordance with the agreement between ODEQ and USEPA relating to administration and enforcement of the delegated NPDES program. Implementation of WLAs for point sources is done through permits issued under the OPDES program. The reduction rates called for in this TMDL report are as high as 99 percent. The ODEQ recognizes that achieving such high reductions will be a challenge, especially since unregulated nonpoint sources are a major cause of both bacteria and TSS loading. The high reduction rates are not uncommon for pathogen- or TSS-impaired waters. Similar reduction rates are often found in other pathogen and TSS TMDLs around the nation.

SECTION 1
INTRODUCTION

1.1 TMDL Program Background

Section 303(d) of the Clean Water Act (CWA) and U.S. Environmental Protection Agency (USEPA) Water Quality Planning and Management Regulations (40 Code of Federal Regulations [CFR] Part 130) require states to develop total maximum daily loads (TMDLs) for waterbodies not meeting designated uses where technology-based controls are in place. TMDLs establish the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and instream water quality conditions, so states can implement water quality-based controls to reduce pollution from point and nonpoint sources and restore and maintain water quality (USEPA 1991).

This report documents the data and assessment used to establish TMDLs for the pathogen indicator bacteria [fecal coliform, *Escherichia coli (E. coli)*, Enterococci] and turbidity for selected waterbodies in the Red River basin. (All future references to bacteria in this document imply these three classes of fecal pathogen indicator bacteria unless specifically stated otherwise.) Elevated levels of pathogen indicator bacteria in aquatic environments indicate that a waterbody is contaminated with human or animal feces and that a potential health risk exists for individuals exposed to the water. Elevated turbidity levels caused by excessive sediment loading and stream bank erosion impact aquatic biological communities. Data assessment and TMDL calculations are conducted in accordance with requirements of Section 303(d) of the CWA, Water Quality Planning and Management Regulations (40 CFR Part 130), USEPA guidance, and Oklahoma Department of Environmental Quality (ODEQ) guidance and procedures. ODEQ is required to submit all TMDLs to USEPA for review and approval. Once the USEPA approves a TMDL, then the waterbody may be moved to Category 4a of a state's Integrated Water Quality Monitoring and Assessment Report, where it remains until compliance with water quality standards (WQS) is achieved (USEPA 2003).

The purpose of this TMDL report is to establish pollutant load allocations for indicator bacteria and turbidity in impaired waterbodies, which is the first step toward restoring water quality and protecting public health. TMDLs determine the pollutant loading a waterbody can assimilate without exceeding the WQS for that pollutant. TMDLs also establish the pollutant load allocation necessary to meet the WQS established for a waterbody based on the relationship between pollutant sources and instream water quality conditions. A TMDL consists of a wasteload allocation (WLA), load allocation (LA), and a margin of safety (MOS). The WLA is the fraction of the total pollutant load apportioned to point sources, and includes stormwater discharges regulated under the National Pollutant Discharge Elimination System (NPDES). The LA is the fraction of the total pollutant load apportioned to nonpoint sources. The MOS is a percentage of the TMDL set aside to account for the lack of knowledge associated with natural process in aquatic systems, model assumptions, and data limitations.

This report does not stipulate specific control actions (regulatory controls) or management measures (voluntary best management practices) necessary to reduce bacteria or turbidity within each watershed. Watershed-specific control actions and management measures will be identified, selected, and implemented under a separate process involving stakeholders who live and work in the watersheds, along with tribes, and local, state, and federal government agencies.

This TMDL report focuses on waterbodies that ODEQ placed in Category 5 [303(d) list] of the *Water Quality in Oklahoma, 2008 Integrated Report* (2008 Integrated Report) for nonsupport of primary body contact recreation (PBCR) or warm water aquatic community (WWAC) designated uses. The waterbodies addressed in this report, which are presented upstream to downstream, include:

- Deer Creek (OK311800000070_00),
- Haystack Creek (OK311800000040_00),
- Sandy Creek (Lebos) (OK311600010040_00),
- Gypsum Creek (OK311600010020_00),
- Sweetwater Creek (OK311510020120_00),
- North Fork of the Red River, SH 34, Carter (OK311510010010_10),
- Elk Creek, SH 19, Roosevelt (OK311500030010_00),
- Otter Creek (OK311500010080_00),
- Stinking Creek OK311500010050_00),
- North Fork of the Red River, US 62, Headrick (OK311500010020_10),
- Brush Creek (OK311310030050_00),
- Little Deep Red Creek (OK311310030040_00),
- Deep Red Creek (OK311310030010_00),
- West Cache Creek, SH5B, Taylor (OK311310020010_00),
- Suttle Creek (OK311310010070_00),
- East Cache Creek, SH 53, Walters (OK311300010020_10),
- Cache Creek, East (OK311300010020_00),
- Dry Creek (OK311200000080_00),
- Cow Creek (OK311200000060_00),
- Beaver Creek (OK311200000030_00),
- Mud Creek, West, Lower (OK311100040080_00),
- Mud Creek (OK311100040010_00),
- Fleetwood Creek (OK311100010300_00), and
- Red Creek (OK311100010290_00).

Figures 1-1 and 1-2 are location maps showing these Oklahoma waterbodies and their contributing watersheds. These maps also display locations of the water quality monitoring (WQM) stations used as the basis for placement of these waterbodies on the Oklahoma 303(d) list. These waterbodies and their surrounding watersheds are hereinafter referred to as the Study Area.

Figure 1-1 Upper Red River Watersheds Not Supporting Primary Body Contact Recreation or Fish and Wildlife Propagation

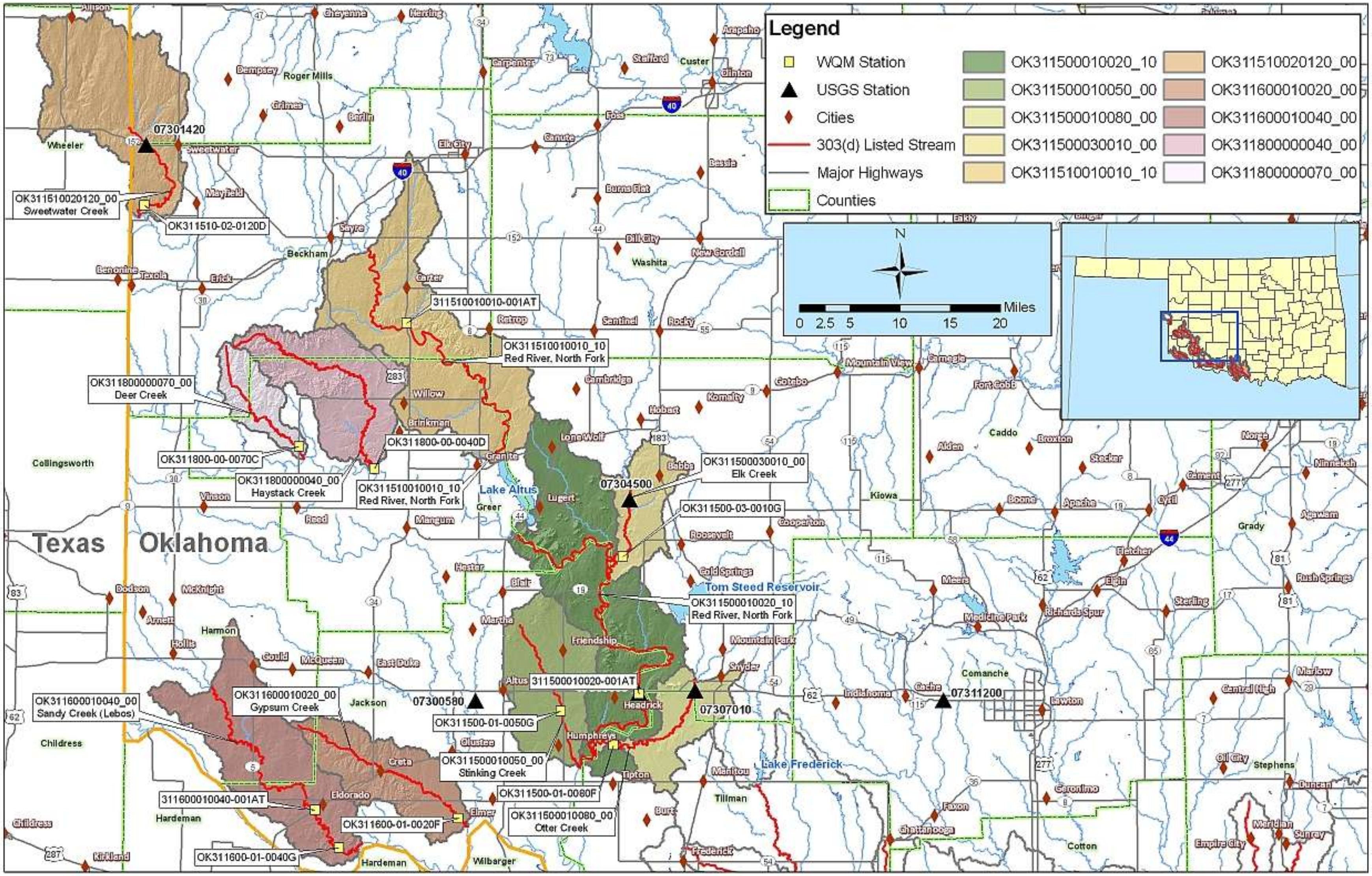
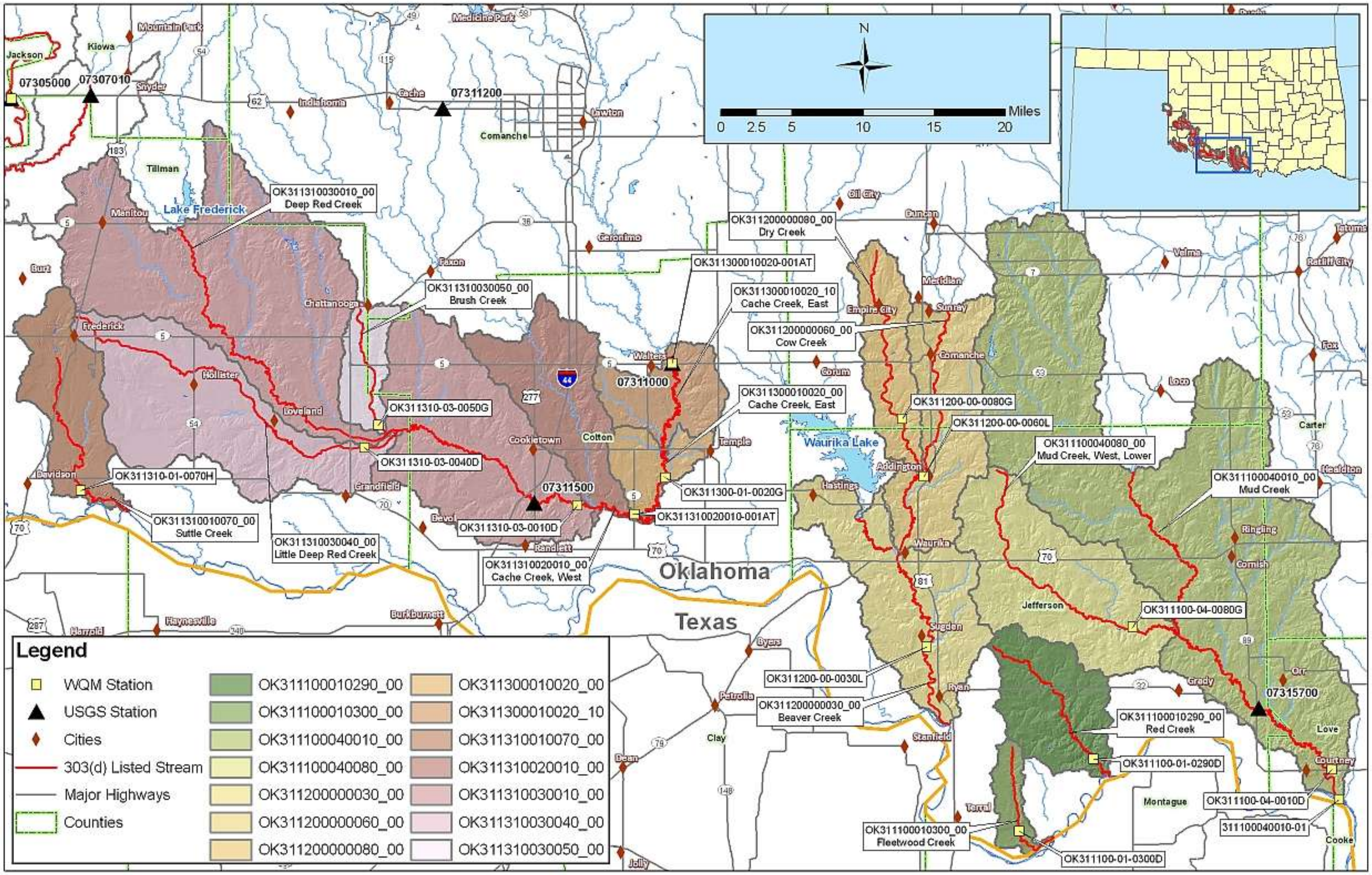


Figure 1-2 Lower Red River Watersheds Not Supporting Primary Body Contact Recreation or Fish and Wildlife Propagation Use



Elevated levels of pathogen indicator bacteria or turbidity above the WQS result in the requirement that a TMDL be developed. The TMDLs established in this report are a necessary step in the process to develop the pollutant loading controls needed to restore the primary body contact recreation or fish and wildlife propagation use designated for each waterbody. Table 1-1 provides a description of the locations of WQM stations on the 303(d)-listed waterbodies.

Table 1-1 Water Quality Monitoring Stations used for 2008 303(d) Listing Decision

WQM Station	Waterbody Name and Station Location	Waterbody ID
OK311800-00-0070C	Deer Creek	OK311800000070_00
OK311800-00-0040D	Haystack Creek	OK311800000040_00
311600010040-001AT	Sandy Creek (Lebos), Eldorado	OK311600010040_00
OK311600-01-0040G	Sandy Creek (Lebos)	OK311600010040_00
OK311600-01-0020F	Gypsum Creek, near Texas border	OK311600010020_00
OK311510-02-0120D	Sweetwater Creek	OK311510020120_00
311510010010-001AT	North Fork of the Red River, SH 34, Carter	OK311510010010_10
OK311500-03-0010G	Elk Creek	OK311500030010_00
OK311500-01-0080F	Otter Creek	OK311500010080_00
OK311500-01-0050G	Stinking Creek	OK311500010050_00
311500010020-001AT	Red River, North Fork, at USGS Station	OK311500010020_10
OK311310-03-0050G	Brush Creek, near Deep Red Creek confluence	OK311310030050_00
OK311310-03-0040D	Little Deep Red Creek, near Deep Red Creek confluence	OK311310030040_00
OK311310-03-0010D	Deep Red Creek, East of USGS Station at HWY 277	OK311310030010_00
311310020010-001AT	Cache Creek, West, SH 5B, Taylor	OK311310020010_00
OK311310-01-0070H	Suttle Creek, near Texas border	OK311310010070_00
311300010020-001AT	Cache Creek, East, at USGS Station	OK311300010020_00
OK311300-01-0020G	Cache Creek, East	OK311300010020_00
OK311200-00-0080G	Dry Creek, near Jefferson Co. line	OK311200000080_00
OK311200-00-0060L	Cow Creek at Addington	OK311200000060_00
OK311200-00-0030L	Beaver Creek, near Sugden	OK311200000030_00
OK311100-04-0080G	West Mud Creek	OK311100040080_00
311100040010-01	Mud Creek, on Texas border	OK311100040010_00
OK311100-04-0010D	Mud Creek, near Courtney	OK311100040010_00
OK311100-01-0300D	Fleetwood Creek, near Texas border	OK311100010300_00
OK311100-01-0290D	Red Creek, near Texas border	OK311100010290_00

1.2 Watershed Description

General. The Red River basin is located in the southwestern portion of Oklahoma. The majority of the waterbodies addressed in this report are located in Beckham, Greer, Harmon, Jackson, Kiowa, Tillman, Cotton, Stephens and Jefferson Counties. The north section of Saltwater Creek (OK311510020120_00) is located in Roger Mills County and the south section of Mud Creek (OK311100040010_00) is located in Love County. These counties are part of the Central Great Plains and Cross Timbers Level III ecoregions (Woods, A.J, Omerik, J.M., et al 2005). The watersheds in the Study Area are located in the Anadarko Basin Wichita Mountain Uplift, Marietta Basin, and the Hollis Basin geological provinces. Table 1-2, derived from the 2000 U.S. Census, demonstrates that the counties in which these watersheds are located are sparsely populated (U.S. Census Bureau 2000). Table 1-3 lists the towns and cities located in each watershed.

Table 1-2 County Population and Density

County Name	Population (2000 Census)	Population Density (per square mile)
Beckham	19,799	22
Love	8,831	17
Jefferson	6,818	9
Kiowa	10,227	10
Jackson	28,439	35
Harmon	3,283	6
Greer	6,061	10
Stephens	43,182	49
Roger Mills	3,436	3
Cotton	6,614	10

Table 1-3 Towns and Cities by Watershed

Waterbody Name	Waterbody ID	Municipalities
Deer Creek	OK311800000070_00	
Haystack Creek	OK311800000040_00	
Sandy Creek (Lebos)	OK311600010040_00	Gould, Eldorado
Gypsum Creek	OK311600010020_00	Creta
Sweetwater Creek	OK311510020120_00	Sweetwater, Allison
North Fork of the Red River, SH 34, Carter	OK311510010010_10	Carter, Willow
Elk Creek, SH 19, Roosevelt	OK311500030010_00	Babbs
Otter Creek	OK311500010080_00	Snyder
Stinking Creek	OK311500010050_00	Humphreys, Friendship, Altus
North Fork of the Red River, US 62, Headrick	OK311500010020_10	Headrick, Lugert, Lone Wolf
Brush Creek	OK311310030050_00	Chattanooga
Little Deep Fed Creek	OK311310030040_00	Loveland, Grandfield, Hollister
Deep Red Creek	OK311310030010_00	Manitou, Cookietown, Randlett
West Cache Creek, SH5B, Taylor	OK311310020010_00	
Suttle Creek	OK311310010070_00	Fredrick
East Cache Creek, SH 53, Walters	OK311300010020_10	Walters
Cache Creek, East	OK311300010020_00	Temple
Dry Creek	OK311200000080_00	Empire City
Cow Creek	OK311200000060_00	Sunrise, Comanche, Meridian, Addington
Beaver Creek	OK311200000030_00	Ryan, Sugden, Waurika, Hastings
Mud Creek, West, Lower	OK311100040080_00	
Mud Creek	OK311100040010_00	Courtney, Orr, Cornish, Ringling
Fleetwood Creek	OK311100010300_00	
Red Creek	OK311100010290_00	

Climate. Table 1-4 summarizes the average annual precipitation for each Oklahoma waterbody based on the approximate midpoint of each watershed. Average annual precipitation values among the watersheds in this portion of Oklahoma range between 24 and 35 inches (Oklahoma Climate Survey 2007).

Table 1-4 Average Annual Precipitation by Watershed

Red River Basin Precipitation Summary		
Waterbody Name	**Waterbody ID**	**Average Annual Precipitation (Inches)**
Deer Creek	OK311800000070_00	27
Haystack Creek	OK311800000040_00	29
Sandy Creek (Lebos)	OK311600010040_00	27
Gypsum Creek	OK311600010020_00	28
Sweetwater Creek	OK311510020120_00	24
North Fork of the Red River, SH 34, Carter	OK311510010010_10	28
Elk Creek, SH 19, Roosevelt	OK311500030010_00	29
Otter Creek	OK311500010080_00	30
Stinking Creek	OK311500010050_00	29
North Fork of the Red River, US 62, Headrick	OK311500010020_10	29
Brush Creek	OK311310030050_00	31
Little Deep Fed Creek	OK311310030040_00	31
Deep Red Creek	OK311310030010_00	31
West Cache Creek, SH5B, Taylor	OK311310020010_00	33
Suttle Creek	OK311310010070_00	30
East Cache Creek, SH 53, Walters	OK311300010020_10	34
Cache Creek, East	OK311300010020_00	33
Dry Creek	OK311200000080_00	35
Cow Creek	OK311200000060_00	35
Beaver Creek	OK311200000030_00	33
Mud Creek, West, Lower	OK311100040080_00	34
Mud Creek	OK311100040010_00	35
Fleetwood Creek	OK311100010300_00	33
Red Creek	OK311100010290_00	34

Land Use. Tables 1-5a and 1-5b summarize the percentages and acreages of the land use categories for the contributing watershed associated with each respective Oklahoma waterbody addressed in the Study Area. The land use/land cover data were derived from the U.S. Geological Survey (USGS) 2001 National Land Cover Dataset (USGS 2007). The land use categories are displayed in Figure 1-3. The three most dominant land use category throughout the Red River Study Area is cultivated crops and grasslands/herbaceous. Four watersheds in the Study Area do have a significant percentage of land use classified as shrub/scrub including Deer Creek (OK311800000070_00), Haystack Creek (OK311800000040_00), Gypsum Creek (OK311600010020_00) and North Fork of the Red River, SH34, Carter (OK311510010010_10). The aggregated total of low, medium, and high intensity developed land account for less than 2 percent of the land use in each watershed, except for Stinking Creek (OK 311500010050_00) which accounts for 4 percent. The watersheds targeted for TMDL development in this Study Area range in size from 10,562 acres (Fleetwood Creek, OK311100010300_00) to 174,419 acres (North Fork of the Red River at SH34, OK311510010010_10).

Figure 1-3 Land Use Map

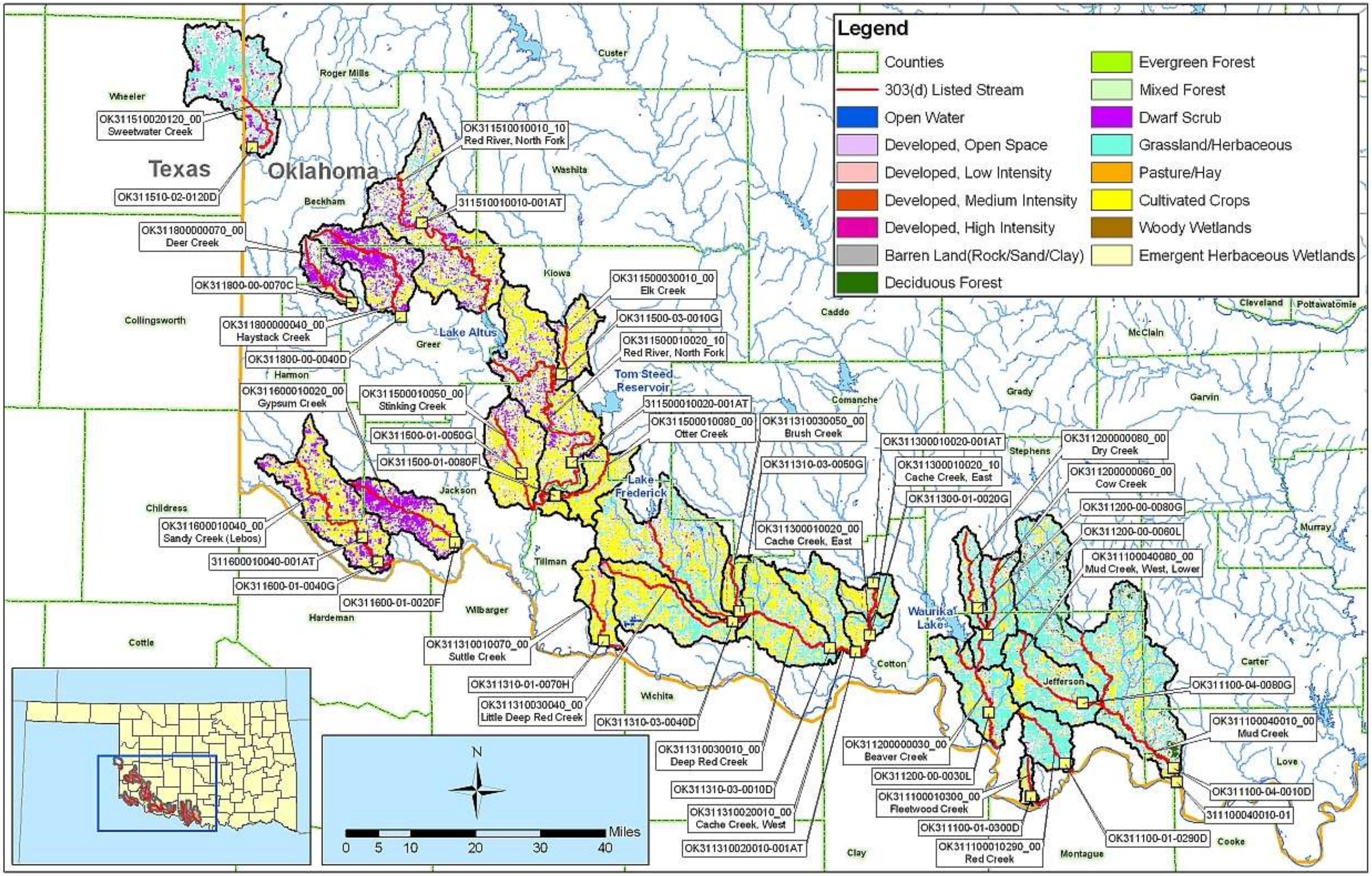


Table 1-5 Land Use Summaries by Watershed

Landuse Category	Watershed					
	Deer Creek	Haystack Creek	Sandy Creek (Lebos)	Gypsum Creek	Sweetwater Creek	North Fork of the Red River, SH 34, Carter
Waterbody ID	**OK311800000070_00**	**OK311800000040_00**	**OK311600010040_00**	**OK311600010020_00**	**OK311510020120_00**	**OK311510010010_10**
Percent of Open Water	0.05%	0.10%	0.04%	0.32%	0.09%	0.27%
Percent of Developed, Open Space	0.69%	1.34%	4.38%	2.59%	1.02%	2.96%
Percent of Developed, Low Intensity	0.00%	0.01%	0.15%	0.28%	0.03%	0.06%
Percent of Developed, Medium Intensity	0.00%	0.00%	0.01%	0.01%	0.00%	0.01%
Percent of Developed, High Intensity	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Percent of Barren Land (Rock/Sand/Clay)	0.12%	1.34%	0.00%	0.17%	0.90%	0.34%
Percent of Deciduous Forest	0.00%	0.00%	0.05%	0.02%	0.03%	0.00%
Percent of Evergreen Forest	0.00%	0.00%	0.05%	0.02%	0.00%	0.00%
Percent of Mixed Forest	0.53%	0.45%	0.90%	0.22%	0.81%	5.64%
Percent of Shrub/Scrub	65.57%	66.85%	40.70%	60.34%	34.07%	39.71%
Percent of Grassland/Herbaceous	21.63%	15.46%	1.95%	2.65%	59.85%	17.09%
Percent of Pasture/Hay	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Percent of Cultivated Crops	11.37%	14.19%	51.74%	33.35%	3.19%	32.71%
Percent of Woody Wetlands	0.04%	0.26%	0.03%	0.03%	0.02%	1.21%
Percent of Emergent Herbaceous Wetlands	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Acres Open Water	14	75	44	216	83	479
Acres Developed, Open Space	204	991	4,304	1,727	924	5,161
Acres Developed, Low Intensity	0	4	150	186	30	111
Acres Developed, Medium Intensity	0	0	10	6	3	14
Acres Developed, High Intensity	0	0	0	0	0	1
Acres Barren Land (Rock/Sand/Clay)	35	993	5	111	818	596
Acres Deciduous Forest	0	0	53	14	23	4
Acres Evergreen Forest	0	0	47	14	4	2
Acres Mixed Forest	157	336	880	148	733	9,829
Acres Shrub/Scrub	19,389	49,482	40,036	40,181	31,019	69,254
Acres Grassland/Herbaceous	6,394	11,445	1,915	1,765	54,500	29,814
Acres Pasture/Hay	0	0	0	0	0	0
Acres Cultivated Crops	3,361	10,507	50,893	22,208	2,905	57,048
Acres Woody Wetlands	12	190	32	17	14	2,104
Acres Emergent Herbaceous Wetlands	0	0	0	0	0	0
Total (Acres)	**29,567**	**74,022**	**98,371**	**66,594**	**91,056**	**174,419**

Landuse Category	Watershed					
	Elk Creek	Otter Creek	Stinking Creek	North Fork of the Red River, US 62, Headrick	Brush Creek	Little Deep Fed Creek
Waterbody ID	**OK311500030010_00**	**OK311500010080_00**	**OK311500010050_00**	**OK311500010020_10**	**OK311310030050_00**	**OK311310030040_00**
Percent of Open Water	0.21%	0.44%	0.21%	1.71%	0.17%	0.29%
Percent of Developed, Open Space	3.62%	4.50%	6.62%	2.81%	4.20%	4.42%
Percent of Developed, Low Intensity	0.04%	1.02%	2.69%	0.10%	0.62%	1.44%
Percent of Developed, Medium Intensity	0.01%	0.06%	0.77%	0.01%	0.10%	0.20%
Percent of Developed, High Intensity	0.00%	0.06%	0.63%	0.00%	0.04%	0.07%
Percent of Barren Land (Rock/Sand/Clay)	0.00%	0.13%	0.05%	0.35%	0.02%	0.01%
Percent of Deciduous Forest	0.00%	2.16%	0.04%	0.35%	0.36%	0.34%
Percent of Evergreen Forest	0.00%	0.00%	0.02%	0.02%	0.00%	0.00%
Percent of Mixed Forest	1.97%	0.30%	2.64%	6.88%	0.00%	0.00%
Percent of Shrub/Scrub	26.50%	5.01%	20.80%	33.15%	0.58%	0.89%
Percent of Grassland/Herbaceous	7.21%	20.08%	4.89%	13.19%	26.39%	37.84%
Percent of Pasture/Hay	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%
Percent of Cultivated Crops	60.44%	66.23%	60.52%	41.43%	67.53%	54.50%
Percent of Woody Wetlands	0.00%	0.01%	0.10%	0.01%	0.00%	0.00%
Percent of Emergent Herbaceous Wetlands	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Acres Open Water	66	195	165	1,893	30	157
Acres Developed, Open Space	1,117	2,013	5,222	3,111	745	2,412
Acres Developed, Low Intensity	11	456	2,125	109	110	787
Acres Developed, Medium Intensity	2	25	607	7	17	107
Acres Developed, High Intensity	0	26	500	0	7	38
Acres Barren Land (Rock/Sand/Clay)	0	58	40	385	3	7
Acres Deciduous Forest	1	964	32	388	64	185
Acres Evergreen Forest	1	0	13	18	0	0
Acres Mixed Forest	609	132	2,084	7,610	0	0
Acres Shrub/Scrub	8,181	2,239	16,402	36,672	103	488
Acres Grassland/Herbaceous	2,226	8,971	3,858	14,589	4,680	20,659
Acres Pasture/Hay	0	6	0	0	0	0
Acres Cultivated Crops	18,661	29,592	47,719	45,824	11,978	29,758
Acres Woody Wetlands	1	3	80	12	0	0
Acres Emergent Herbaceous Wetlands	0	0	0	0	0	0
Total (Acres)	**30,877**	**44,680**	**78,847**	**110,618**	**17,738**	**54,599**

Landuse Category	Watershed					
	Deep Red Creek	West Cache Creek, SH5B, Taylor	Suttle Creek	East Cache Creek, SH 53, Walters	Cache Creek, East	Dry Creek
Waterbody ID	**OK311310030010_00**	**OK311310020010_00**	**OK311310010070_00**	**OK311300010020_10**	**OK311300010020_00**	**OK311200000080_00**
Percent of Open Water	0.27%	0.28%	0.43%	0.23%	0.43%	0.50%
Percent of Developed, Open Space	3.88%	4.87%	5.49%	4.38%	5.75%	4.02%
Percent of Developed, Low Intensity	0.16%	0.48%	1.24%	0.87%	0.37%	0.10%
Percent of Developed, Medium Intensity	0.12%	0.21%	0.34%	0.11%	0.08%	0.03%
Percent of Developed, High Intensity	0.00%	0.03%	0.25%	0.00%	0.01%	0.01%
Percent of Barren Land (Rock/Sand/Clay)	0.05%	0.02%	0.48%	0.01%	0.07%	0.00%
Percent of Deciduous Forest	2.88%	5.27%	0.42%	4.27%	5.28%	12.77%
Percent of Evergreen Forest	0.00%	0.01%	0.00%	0.00%	0.00%	0.01%
Percent of Mixed Forest	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Percent of Shrub/Scrub	3.40%	0.73%	0.51%	0.48%	0.72%	0.02%
Percent of Grassland/Herbaceous	42.41%	39.23%	15.42%	40.85%	36.01%	66.11%
Percent of Pasture/Hay	0.03%	0.06%	0.06%	0.20%	0.00%	0.09%
Percent of Cultivated Crops	46.78%	48.80%	75.36%	48.60%	51.29%	16.35%
Percent of Woody Wetlands	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Percent of Emergent Herbaceous Wetlands	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%
Acres Open Water	278	137	176	65	74	157
Acres Developed, Open Space	4,048	2,376	2,250	1,249	999	1,265
Acres Developed, Low Intensity	169	234	507	249	64	32
Acres Developed, Medium Intensity	127	104	138	31	13	9
Acres Developed, High Intensity	3	14	103	1	2	2
Acres Barren Land (Rock/Sand/Clay)	50	10	196	3	12	0
Acres Deciduous Forest	3,004	2,573	171	1,218	919	4,018
Acres Evergreen Forest	5	5	0	0	0	2
Acres Mixed Forest	0	0	0	0	0	0
Acres Shrub/Scrub	3,546	359	210	136	125	5
Acres Grassland/Herbaceous	44,230	19,151	6,319	11,641	6,264	20,799
Acres Pasture/Hay	34	28	26	57	0	27
Acres Cultivated Crops	48,792	23,822	30,888	13,851	8,921	5,143
Acres Woody Wetlands	0	0	0	0	0	0
Acres Emergent Herbaceous Wetlands	6	1	1	0	0	0
Total (Acres)	**104,291**	**48,814**	**40,986**	**28,499**	**17,393**	**31,461**

Landuse Category	Watershed					
	Cow Creek	Beaver Creek	Mud Creek, West, Lower	Mud Creek	Fleetwood Creek	Red Creek
Waterbody ID	**OK311200000060_00**	**OK311200000030_00**	**OK311100040080_00**	**OK311100040010_00**	**OK311100010300_00**	**OK311100010290_00**
Percent of Open Water	0.51%	0.46%	0.48%	0.42%	0.05%	0.50%
Percent of Developed, Open Space	5.45%	4.98%	1.41%	2.10%	2.86%	1.94%
Percent of Developed, Low Intensity	1.43%	0.77%	0.05%	0.05%	0.00%	0.02%
Percent of Developed, Medium Intensity	0.40%	0.32%	0.00%	0.00%	0.00%	0.00%
Percent of Developed, High Intensity	0.04%	0.05%	0.00%	0.00%	0.00%	0.00%
Percent of Barren Land (Rock/Sand/Clay)	0.03%	0.01%	0.01%	0.02%	0.00%	0.02%
Percent of Deciduous Forest	12.66%	7.63%	6.44%	17.49%	9.64%	4.89%
Percent of Evergreen Forest	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%
Percent of Mixed Forest	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Percent of Shrub/Scrub	0.18%	0.35%	0.10%	0.04%	2.42%	2.29%
Percent of Grassland/Herbaceous	67.07%	59.02%	69.09%	61.00%	47.17%	78.32%
Percent of Pasture/Hay	0.00%	0.42%	3.64%	7.79%	2.43%	2.55%
Percent of Cultivated Crops	12.23%	25.97%	18.78%	11.08%	35.44%	9.47%
Percent of Woody Wetlands	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Percent of Emergent Herbaceous Wetlands	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Acres Open Water	198	249	331	436	5	201
Acres Developed, Open Space	2,124	2,703	978	2,165	302	786
Acres Developed, Low Intensity	559	420	32	48	0	6
Acres Developed, Medium Intensity	157	173	2	0	0	0
Acres Developed, High Intensity	14	30	0	0	0	0
Acres Barren Land (Rock/Sand/Clay)	11	6	4	20	0	8
Acres Deciduous Forest	4,937	4,140	4,461	18,059	1,018	1,976
Acres Evergreen Forest	0	1	2	14	0	0
Acres Mixed Forest	0	0	0	0	0	0
Acres Shrub/Scrub	71	191	67	41	256	927
Acres Grassland/Herbaceous	26,163	32,041	47,873	62,975	4,982	31,665
Acres Pasture/Hay	0	231	2,524	8,040	257	1,033
Acres Cultivated Crops	4,771	14,099	13,015	11,435	3,743	3,829
Acres Woody Wetlands	0	0	0	0	0	0
Acres Emergent Herbaceous Wetlands	0	2	0	2	0	0
Total (Acres)	**39,006**	**54,285**	**69,290**	**103,235**	**10,562**	**40,432**

1.3 Stream Flow Conditions

Stream flow characteristics and data are key information when conducting water quality assessments such as TMDLs. The USGS operates flow gages throughout Oklahoma, from which long-term stream flow records can be obtained. At various WQM stations additional flow measurements are available which were collected at the same time bacteria, total suspended solids (TSS) and turbidity water quality samples were collected. Not all of the waterbodies in this Study Area have historical flow data available. However, the flow data from the surrounding USGS gage stations and the instantaneous flow measurement data along with water quality samples have been used to estimate flows for ungaged streams. Flow data collected at the time of water quality sampling are included in Appendix A along with corresponding water chemistry data results. A summary of the method used to project flows for ungaged streams and flow exceedance percentiles from projected flow data are provided in Appendix B.

SECTION 2
PROBLEM IDENTIFICATION AND WATER QUALITY TARGET

2.1 Oklahoma Water Quality Standards

Title 785 of the Oklahoma Administrative Code contains Oklahoma's water quality standards and implementation procedures (OWRB 2008). The Oklahoma Water Resources Board (OWRB) has statutory authority and responsibility concerning establishment of state water quality standards, as provided under 82 Oklahoma Statute [O.S.], §1085.30. This statute authorizes the OWRB to promulgate rules …*which establish classifications of uses of waters of the state, criteria to maintain and protect such classifications, and other standards or policies pertaining to the quality of such waters.* [O.S. 82:1085:30(A)]. Beneficial uses are designated for all waters of the state. Such uses are protected through restrictions imposed by the antidegradation policy statement, narrative water quality criteria, and numerical criteria (OWRB 2008). An excerpt of the Oklahoma WQS (Title 785) summarizing the State of Oklahoma Antidegradation Policy is provided in Appendix D. Table 2-1a, an excerpt from the 2008 Integrated Report (ODEQ 2008), lists beneficial uses designated for each bacteria and/or turbidity impaired stream segment in the Study Area. The beneficial uses include:

- AES – Aesthetics
- AG – Agriculture Water Supply
- HLAC – Habitat Limited Aquatic Community
- WWAC – Warm Water Aquatic Community
- FISH – Fish Consumption
- PBCR – Primary Body Contact Recreation
- SBCR – Secondary Body Contact Recreation
- PPWS – Public & Private Water Supply
- EWS – Emergency Water Supply

Table 2-1 summarizes the PBCR and WWAC use attainment status and the bacteria & turbidity impairment status for streams in the Study Area. The TMDL priority shown in Table 2-1 is directly related to the TMDL target date. The TMDLs established in this report, which are a necessary step in the process of restoring water quality, only address bacteria and/or turbidity impairments that affect the PBCR and WWAC-beneficial uses.

The definition of PBCR is summarized by the following excerpt from Chapter 45 of the Oklahoma WQSs.

(a) *Primary Body Contact Recreation involves direct body contact with the water where a possibility of ingestion exists. In these cases the water shall not contain chemical, physical or biological substances in concentrations that are irritating to skin or sense organs or are toxic or cause illness upon ingestion by human beings.*

(b) *In waters designated for Primary Body Contact Recreation...limits...shall apply only during the recreation period of May 1 to September 30. The criteria for Secondary Body Contact Recreation will apply during the remainder of the year.*

Table 2-1 Excerpt from the 2008 Integrated Report – Oklahoma 303(d) List of Impaired Waters (Category 5)

Waterbody ID	Waterbody Name	Stream Miles	TMDL Date	Priority	ENT	*E. coli*	FC	Designated Use Primary Body Contact Recreation	Turbidity	Designated Use Warm Water Aquatic Life
OK311800000070_00	Deer Creek	22.21	2019	4					X	N
OK311800000040_00	Haystack Creek	43.06	2016	3	X	X		N	X	N
OK311600010040_00	Sandy Creek (Lebos)	39.65	2013	2					X	N
OK311600010020_00	Gypsum Creek	28.1	2016	3	X			N	X	N
OK311510020120_00	Sweetwater Creek	16.43	2019	4	X	X		N	X	N
OK311510010010_10	North Fork of the Red River, SH 34, Carter	47.29	2019	4	X			N	X	N
OK311500030010_00	Elk Creek, SH 19, Roosevelt	15.7	2019	4					X	N
OK311500010080_00	Otter Creek	23.13	2010	1	X	X		N	X	N
OK311500010050_00	Stinking Creek	17.44	2016	3					X	N
OK311500010020_10	North Fork of the Red River, US 62, Headrick	61.7	2016	3					X	N
OK311310030050_00	Brush Creek	11.64	2016	3					X	N
OK311310030040_00	Little Deep Red Creek	33.57	2013	2					X	N
OK311310030010_00	Deep Red Creek	57.29	2016	3	X	X		N	X	N
OK311310020010_00	West Cache Creek, SH5B, Taylor	9.1	2019	4					X	N
OK311310010070_00	Suttle Creek	19.41	2019	4					X	N
OK311300010020_10	East Cache Creek, SH 53, Walters	17.11	2013	2					X	N
OK311300010020_00	Cache Creek, East	9.05	2013	2					X	N
OK311200000080_00	Dry Creek	20.96	2013	2	X	X	X	N	X	N
OK311200000060_00	Cow Creek	25.73	2013	2					X	N
OK311200000030_00	Beaver Creek	26.44	2010	1	X			N	X	N
OK311100040080_00	Mud Creek, West, Lower	27.81	2013	2					X	N
OK311100040010_00	Mud Creek	49.53	2013	2					X	N
OK311100010300_00	Fleetwood Creek	10.91	2019	4					X	N
OK311100010290_00	Red Creek	17.42	2016	3	X	X		N	X	N

ENT = enterococci; FC = fecal coliform
N = Not attaining; X = Criterion exceeded
Source: 2008 Integrated Report, ODEQ 2008.

Table 2-1a Designated Beneficial Uses for Each Impaired Waterbody in the Study Area

Waterbody ID	Waterbody Name	AES	AG	HLAC	WWAC	*FISH*	PBCR	SBCR	PPWS	EWS
OK311800000070_00	Deer Creek	F	N		N	X	N		F	
OK311800000040_00	Haystack Creek	F	N		N	X	N		I	
OK311600010040_00	Sandy Creek (Lebos)	F	N	N		F		N		F
OK311600010020_00	Gypsum Creek	F	N		N	X	N		I	
OK311510020120_00	Sweetwater Creek	F	N		N	X	N		I	
OK311510010010_10	North Fork of the Red River, SH 34, Carter	I	F		N	F	N		N	
OK311500030010_00	Elk Creek, SH 19, Roosevelt	F	F		N	F	N		I	
OK311500010080_00	Otter Creek	I	N		N	X	N		I	
OK311500010050_00	Stinking Creek	F	N		N	X	N		N	
OK311500010020_10	North Fork of the Red River, US 62, Headrick	I	N		N	F	N		I	
OK311310030050_00	Brush Creek	N	N		N	X	N			
OK311310030040_00	Little Deep Red Creek	N	N		N	X	I		I	
OK311310030010_00	Deep Red Creek	I	N		N	X	N		I	
OK311310020010_00	West Cache Creek, SH5B, Taylor	I	N		N	I	N		I	
OK311310010070_00	Suttle Creek	F	N		N	X		I		
OK311300010020_10	East Cache Creek, SH 53, Walters	I	N		N	N	N		I	
OK311300010020_00	Cache Creek, East	I	N		N	N	N		I	
OK311200000080_00	Dry Creek	F	N		N	X	N		I	
OK311200000060_00	Cow Creek	F	N		N	I	N			F
OK311200000030_00	Beaver Creek	I	N		N	X	N		I	
OK311100040080_00	Mud Creek, West, Lower	F	F		N	X	N			
OK311100040010_00	Mud Creek	I	F		N	N	N		I	
OK311100010300_00	Fleetwood Creek	I	F		N	X	I		I	
OK311100010290_00	Red Creek	F	F		N	X	N		I	

F – Fully supporting; N – Not supporting; I – Insufficient information; X – Not assessed

To implement Oklahoma's WQS for PBCR, OWRB promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2008a). The excerpt below from Chapter 46: 785:46-15-6, stipulates how water quality data will be assessed to determine support of the PBCR use as well as how the water quality target for TMDLs will be defined for each bacterial indicator.

(a) Scope. The provisions of this Section shall be used to determine whether the subcategory of Primary Body Contact of the beneficial use of Recreation designated in OAC 785:45 for a waterbody is supported during the recreation season from May 1 through September 30 each year. Where data exist for multiple bacterial indicators on the same waterbody or waterbody segment, the determination of use support shall be based upon the use and application of all applicable tests and data.

(b) Screening levels.

(1) The screening level for fecal coliform shall be a density of 400 colonies per 100 ml.

(2) The screening level for Escherichia coli shall be a density of 235 colonies per 100 ml in streams designated in OAC 785:45 as Scenic Rivers and in lakes, and 406 colonies per 100 ml in all other waters of the state designated as Primary Body Contact Recreation.

(3) The screening level for enterococci shall be a density of 61 colonies per 100 ml in streams designated in OAC 785:45 as Scenic Rivers and in lakes, and 108 colonies per 100 ml in all other waters of the state designated as Primary Body Contact Recreation.

(c) Fecal coliform:

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to fecal coliform if the geometric mean of 400 colonies per 100 ml is met and no greater than 25% of the sample concentrations from that waterbody exceed the screening level prescribed in (b) of this Section.

(2) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to fecal coliform if the geometric mean of 400 colonies per 100 ml is not met, or greater than 25% of the sample concentrations from that waterbody exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

(d) Escherichia coli (E. coli):

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to E. coli if the geometric mean of 126 colonies per 100 ml is met, or the sample concentrations from that waterbody taken during the recreation season do not exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

(2) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to E. coli if the geometric mean of 126 colonies per 100 ml is not met and any of the sample concentrations from that waterbody taken during the recreation season exceed a screening level prescribed in (b) of this Section.

(e) Enterococci:

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to enterococci if the geometric mean of 33 colonies per 100 ml is met, or the sample concentrations from that waterbody taken during the recreation season do not exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

(2) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to enterococci if the geometric mean of 33 colonies per 100 ml is not met and any of the sample concentrations from that waterbody taken during the recreation season exceed a screening level prescribed in (b) of this Section.

Compliance with the Oklahoma WQS is based on meeting requirements for all three bacterial indicators. Where concurrent data exist for multiple bacterial indicators on the same waterbody or waterbody segment, each indicator group must demonstrate compliance with the numeric criteria prescribed (OWRB 2008).

As stipulated in the WQS, utilization of the geometric mean to determine compliance for any of the three indicator bacteria depends on the collection of five samples within a 30-day period. For most WQM stations in Oklahoma there are insufficient data available to calculate the 30-day geometric mean since most water quality samples are collected once a month. As a result, waterbodies placed on the 303(d) list for not supporting the PBCR are the result of individual samples exceeding the instantaneous criteria or the long-term geometric mean of individual samples exceeding the geometric mean criteria for each respective bacterial indicator. Targeting the instantaneous criterion established for the primary contact recreation season (May 1st to September 30th) as the water quality goal for TMDLs corresponds to the basis for 303(d) listing and may be protective of the geometric mean criterion as well as the criteria for the secondary contact recreation season. However, both the instantaneous and geometric mean criteria for *E. coli* and Enterococci will be evaluated as water quality targets to ensure the most protective goal is established for each waterbody.

A sample quantity exception exists for fecal coliform that allows waterbodies to be listed for nonsupport of PBCR if there are less than 10 samples. The assessment method states that if there are less than 10 samples and the existing sample set already assures a nonsupport determination, then the waterbody should be listed for TMDL development. This condition is true in any case where the small sample set demonstrates that at least three out of six samples exceed the single sample fecal coliform criterion. In this case if four more samples were available to meet minimum of 10 samples, this would still translate to >25 percent exceedance or nonsupport of PBCR (*i.e.*, three out of 10 samples = 33 percent exceedance). For *E. coli* and Enterococci, the 10-sample minimum was used, without exception, in attainment determination.

The beneficial use of WWAC is one of several subcategories of the Fish and Wildlife Propagation use established to manage the variety of communities of fish and shellfish throughout the state (OWRB 2008). The numeric criteria for turbidity to maintain and protect the use of "Fish and Wildlife Propagation" from Title 785:45-5-12 (f) (7) is as follows:

(A) Turbidity from other than natural sources shall be restricted to not exceed the following numerical limits:

i. Cool Water Aquatic Community/Trout Fisheries: 10 NTUs;

ii. Lakes: 25 NTU; and

iii. Other surface waters: 50 NTUs.

(B) In waters where background turbidity exceeds these values, turbidity from point sources will be restricted to not exceed ambient levels.

(C) Numerical criteria listed in (A) of this paragraph apply only to seasonal base flow conditions.

(D) Elevated turbidity levels may be expected during, and for several days after, a runoff event.

To implement Oklahoma's WQS for Fish and Wildlife Propagation, promulgated Chapter 46, *Implementation of Oklahoma's Water Quality Standards* (OWRB 2008a). The excerpt below from Chapter 46: 785:46-15-5, stipulates how water quality data will be assessed to determine support of fish and wildlife propagation as well as how the water quality target for TMDLs will be defined for turbidity.

Assessment of Fish and Wildlife Propagation support

(a) Scope. The provisions of this Section shall be used to determine whether the beneficial use of Fish and Wildlife Propagation or any subcategory thereof designated in OAC 785:45 for a waterbody is supported.

(e) Turbidity. The criteria for turbidity stated in 785:45-5-12(f)(7) shall constitute the screening levels for turbidity. The tests for use support shall follow the default protocol in 785:46-15-4(b).

785:46-15-4. Default protocols

(b) Short term average numerical parameters.

(1) Short term average numerical parameters are based upon exposure periods of less than seven days. Short term average parameters to which this Section applies include, but are not limited to, sample standards and turbidity.

(2) A beneficial use shall be deemed to be fully supported for a given parameter whose criterion is based upon a short term average if 10% or less of the samples for that parameter exceed the applicable screening level prescribed in this Subchapter.

(3) A beneficial use shall be deemed to be fully supported but threatened if the use is supported currently but the appropriate state environmental agency determines that available data indicate that during the next five years the use may become not supported due to anticipated sources or adverse trends of pollution not prevented or controlled. If data from the preceding two year period indicate a trend away from impairment, the appropriate agency shall remove the threatened status.

(4) A beneficial use shall be deemed to be not supported for a given parameter whose criterion is based upon a short term average if at least 10% of the samples for that parameter exceed the applicable screening level prescribed in this Subchapter.

2.2 Problem Identification

In this subsection water quality data summarizing waterbody impairments caused by elevated levels of bacteria are summarized first followed by the data summarizing impairments caused by elevated levels of turbidity.

2.2.1 Bacteria Data Summary

Table 2-2 summarizes water quality data collected during primary contact recreation season from the WQM stations between 2002 and 2009 for each indicator bacteria. The data summary in Table 2-2 provides a general understanding of the amount of water quality data available and the severity of exceedances of the water quality criteria. This data collected during the primary contact recreation season was used to support the decision to place specific waterbodies within the Study Area on the ODEQ 2008 303(d) list (ODEQ 2008). Water quality data from the primary contact recreation seasons are provided in Appendix A. For the data collected between 2000 and 2009, evidence of nonsupport of the PBCR use based on elevated fecal coliform, *E. coli* and Enterococci concentrations was only observed in Dry Creek (OK311200000080_00). Evidence of nonsupport of the PBCR use based on *E. coli* and Enterococci exceedances was observed in five waterbodies: Haystack Creek (OK311800000040_00), Sweetwater Creek (OK311510020120_00), Otter Creek (OK311500010080_00), Deep Red Creek (OK311310030010_00), and Red Creek (OK311100010290_00). Evidence of nonsupport of the PBCR use based on Enterococci exceedances was observed in three waterbodies: Gypsum Creek (OK311600010020_00), North Fork of the Red River, SH 34, Carter (OK311510010010_10) and Beaver Creek (OK311200000030_00).

2.2.2 Turbidity Data Summary

Turbidity is a measure of water clarity and is caused by suspended particles in the water column. Because turbidity cannot be expressed as a mass load, total suspended solids (TSS) are used as a surrogate in this TMDL. Therefore, both turbidity and TSS data are presented in this subsection.

Table 2-3 summarizes water quality data collected from the WQM stations between 1998 and 2009 for turbidity. However, as stipulated in Title *785:45-5-12 (f) (7) (C)*, numeric criteria for turbidity only apply under base flow conditions. While the base flow condition is not specifically defined in the Oklahoma Water Quality Standards, ODEQ considers base flow conditions to be all flows less than the 25th flow exceedance percentile (i.e., the lower 75 percent of flows) which is consistent with the USGS Streamflow Conditions Index (USGS 2007a). Therefore, Table 2-4 was prepared to represent the subset of these data for samples collected during base flow conditions. Water quality samples collected under flow conditions greater than the 25th flow exceedance percentile (highest flows) were therefore excluded from the data set used for TMDL analysis. The data in Table 2-4 were used to support the decision to place all 24 of the waterbodies listed in Table 2-1 on the ODEQ 2008 303(d) list (ODEQ 2008) for nonsupport of the WWAC use based on turbidity levels observed in the waterbody. Table 2-5 summarizes water quality data collected from the WQM stations between 1998 and 2009 for TSS. Table 2-6 presents a subset of these data for samples collected during base flow conditions. In using TSS as a surrogate to support TMDL development at least 10 TSS samples are required to conduct the regression analysis between turbidity and TSS. Water quality data for turbidity and TSS are provided in Appendix A.

Table 2-2 Summary of Indicator Bacteria Samples from Primary Body Contact Recreation Season, 2000-2009

Waterbody ID	Waterbody Name	Indicator	Number of samples	Geometric Mean Concentration (count/100 ml)	Number of samples exceeding single sample criterion	% samples exceeding single sample criterion	2008 303(d)	Notes
OK311800000040_00	Haystack Creek	EC	11	186	3	27%	X	TMDL required
		ENT	11	231	8	73%	X	TMDL required
OK311600010020_00	Gypsum Creek	EC	11	114	1	9%		Not Impaired
		ENT	11	205	8	73%	X	TMDL required
OK311510020120_00	Sweetwater Creek	EC	11	354	5	45%	X	TMDL required
		ENT	11	207	9	82%	X	TMDL required
OK311510010010_10	North Fork of the Red River, SH 34, Carter	EC	19	41	1	5%		Not Impaired
		ENT	19	34	3	16%	X	TMDL required
OK311500010080_00	Otter Creek	EC	11	178	3	27%	X	TMDL required
		ENT	11	159	7	64%	X	TMDL required
OK311310030010_00	Deep Red Creek	EC	11	304	4	36%	X	TMDL required
		ENT	11	325	9	82%	X	TMDL required
OK311200000080_00	Dry Creek	FC	6	456	2	33%	X	Delist: Insufficient number of samples
		EC	4	273	1	25%	X	Delist: Insufficient number of samples
		ENT	4	501	3	75%	X	Delist: Insufficient number of samples
OK311200000030_00	Beaver Creek	EC	10	111	3	30%		Not Impaired
		ENT	10	92	5	50%	X	TMDL required
OK311100010290_00	Red Creek	EC	10	173	5	50%	X	TMDL required
		ENT	10	209	6	60%	X	TMDL required

Fecal coliform (FC) water quality criterion = Geometric Mean of 400 counts/100 mL
E. coli (EC) water quality criterion = Geometric Mean of 126 counts/100 mL
Enterococci (ENT) water quality criterion = Geometric Mean of 33 counts/100 mL

Table 2-3 Summary of All Turbidity Samples, 1998-2009

Waterbody ID	Waterbody Name	WQM Stations	Number of turbidity samples	Number of samples greater than 50 NTU	% samples exceeding criterion	Average Turbidity (NTU)
OK311800000070_00	Deer Creek	OK311800000070C	19	7	37%	52
OK311800000040_00	Haystack Creek	OK311800-00-0040D	20	7	35%	134
OK311600010040_00	Sandy Creek (Lebos)	OK311600010040-001AT,SWQ3	117	49	42%	72
OK311600010020_00	Gypsum Creek	21-4-1	20	6	30%	116
OK311510020120_00	Sweetwater Creek	311510020120-03	20	3	15%	40
OK311510010010_10	North Fork of the Red River, SH 34, Carter	311510010010-001AT	95	22	23%	62
OK311500030010_00	Elk Creek, SH 19, Roosevelt	OK311500030010-001AT,W84ELEC09	155	66	43%	135
OK311500010080_00	Otter Creek	OK311500-01-0080F	19	7	37%	136
OK311500010050_00	Stinking Creek	OK311500010050G	21	9	43%	110
OK311500010020_10	North Fork of the Red River, US 62, Headrick	OK311500010020-001AT	137	38	28%	154
OK311310030050_00	Brush Creek	OK311310030050G	19	10	53%	153
OK311310030040_00	Little Deep Red Creek	OK311310-03-0040D	17	5	29%	119
OK311310030010_00	Deep Red Creek	OK311310-03-0010D	20	14	70%	202
OK311310020010_00	West Cache Creek, SH5B, Taylor	OK311310020010-001AT,OK311310-02-0010M	101	40	40%	139
OK311310010070_00	Suttle Creek	400265	13	8	62%	183
OK311300010020_10	East Cache Creek, SH 53, Walters	11300010020-001AT	94	51	54%	94
OK311300010020_00	Cache Creek, East	OK311300010020-001AT,OKS0104	20	13	65%	159
OK311200000080_00	Dry Creek	OK311200000080G	17	5	29%	94
OK311200000060_00	Cow Creek	OK311200-00-0060L	59	36	61%	116
OK311200000030_00	Beaver Creek	311200000060-01,OK311200-00-0030L	20	10	50%	114
OK311100040080_00	Mud Creek, Lower West	OK311100040080G	22	20	91%	232
OK311100040010_00	Mud Creek	OK311100040010-001AT,OK311100-04-0010D	97	71	73%	197
OK311100010300_00	Fleetwood Creek	OK311100-01-0300D	17	8	47%	134
OK311100010290_00	Red Creek	OK311100-01-0290D	20	9	45%	249

Table 2-4 Summary of Turbidity Samples Collected During Base Flow Conditions, 1998-2009

Waterbody ID	Waterbody Name	WQM Stations	Number of turbidity samples	Number of samples greater than 50 NTU	% samples exceeding criterion	Average Turbidity (NTU)
OK311800000070_00	Deer Creek	OK311800000070C	19	7	37%	52
OK311800000040_00	Haystack Creek	OK311800-00-0040D	20	7	35%	134
OK311600010040_00	Sandy Creek (Lebos)	OK311600010040-001AT,SWQ3	117	49	42%	72
OK311600010020_00	Gypsum Creek	21-4-1	19	5	26%	98
OK311510020120_00	Sweetwater Creek	311510020120-03	19	3	16%	42
OK311510010010_10	North Fork of the Red River, SH 34, Carter	311510010010-001AT	68	5	7%	25
OK311500030010_00	Elk Creek, SH 19, Roosevelt	OK311500030010-001AT,W84ELEC09	150	63	42%	130
OK311500010080_00	Otter Creek	OK311500-01-0080F	17	6	35%	107
OK311500010050_00	Stinking Creek	OK311500010050G	20	8	40%	66
OK311500010020_10	North Fork of the Red River, US 62, Headrick	OK311500010020-001AT	113	17	15%	76
OK311310030050_00	Brush Creek	OK311310030050G	14	7	50%	117
OK311310030040_00	Little Deep Red Creek	OK311310-03-0040D	17	5	29%	119
OK311310030010_00	Deep Red Creek	OK311310-03-0010D	16	10	63%	122
OK311310020010_00	West Cache Creek, SH5B, Taylor	OK311310020010-001AT,OK311310-02-0010M	66	14	21%	47
OK311310010070_00	Suttle Creek	400265	12	7	58%	115
OK311300010020_10	East Cache Creek, SH 53, Walters	11300010020-001AT	64	27	42%	51
OK311300010020_00	Cache Creek, East	OK311300010020-001AT,OKS0104	17	10	59%	75
OK311200000080_00	Dry Creek	OK311200000080G	17	5	29%	94
OK311200000060_00	Cow Creek	OK311200-00-0060L	43	25	58%	99
OK311200000030_00	Beaver Creek	311200000060-01,OK311200-00-0030L	16	7	44%	69
OK311100040080_00	Mud Creek, Lower West	OK311100040080G	20	18	90%	222
OK311100040010_00	Mud Creek	OK311100040010-001AT,OK311100-04-0010D	77	54	70%	132
OK311100010300_00	Fleetwood Creek	OK311100-01-0300D	14	6	43%	135
OK311100010290_00	Red Creek	OK311100-01-0290D	20	9	45%	249

Table 2-5 Summary of All TSS Samples, 1998-2009

Waterbody ID	Waterbody Name	WQM Stations	Number of TSS samples	Average TSS (mg/L)
OK311800000070_00	Deer Creek	OK311800000070C	18	51
OK311800000040_00	Haystack Creek	OK311800-00-0040D	20	293
OK311600010040_00	Sandy Creek (Lebos)	OK311600010040-001AT,SWQ3	43	64
OK311600010020_00	Gypsum Creek	21-4-1	20	101
OK311510020120_00	Sweetwater Creek	311510020120-03	20	59
OK311510010010_10	North Fork of the Red River, SH 34, Carter	311510010010-001AT	21	73
OK311500030010_00	Elk Creek, SH 19, Roosevelt	OK311500030010-001AT,W84ELEC09	42	150
OK311500010080_00	Otter Creek	OK311500-01-0080F	19	104
OK311500010050_00	Stinking Creek	OK311500010050G	20	121
OK311500010020_10	North Fork of the Red River, US 62, Headrick	OK311500010020-001AT	23	170
OK311310030050_00	Brush Creek	OK311310030050G	18	107
OK311310030040_00	Little Deep Red Creek	OK311310-03-0040D	17	81
OK311310030010_00	Deep Red Creek	OK311310-03-0010D	20	127
OK311310020010_00	West Cache Creek, SH5B, Taylor	OK311310020010-001AT,OK311310-02-0010M	34	173
OK311310010070_00	Suttle Creek	400265	13	164
OK311300010020_10	East Cache Creek, SH 53, Walters	11300010020-001AT	22	123
OK311300010020_00	Cache Creek, East	OK311300010020-001AT,OKS0104	20	137
OK311200000080_00	Dry Creek	OK311200000080G	16	35
OK311200000060_00	Cow Creek	OK311200-00-0060L	41	103
OK311200000030_00	Beaver Creek	311200000060-01,OK311200-00-0030L	20	91
OK311100040080_00	Mud Creek, Lower West	OK311100040080G	20	105
OK311100040010_00	Mud Creek	OK311100040010-001AT,OK311100-04-0010D	26	155
OK311100010300_00	Fleetwood Creek	OK311100-01-0300D	18	66
OK311100010290_00	Red Creek	OK311100-01-0290D	21	128

Table 2-6 Summary of TSS Samples During Base Flow Conditions 1998-2009

Waterbody ID	Waterbody Name	WQM Stations	Number of TSS samples	Average TSS (mg/L)
OK311800000070_00	Deer Creek	OK311800000070C	18	51
OK311800000040_00	Haystack Creek	OK311800-00-0040D	20	293
OK311600010040_00	Sandy Creek (Lebos)	OK311600010040-001AT,SWQ3	43	64
OK311600010020_00	Gypsum Creek	21-4-1	19	94
OK311510020120_00	Sweetwater Creek	311510020120-03	18	60
OK311510010010_10	North Fork of the Red River, SH 34, Carter	311510010010-001AT	13	27
OK311500030010_00	Elk Creek, SH 19, Roosevelt	OK311500030010-001AT,W84ELEC09	39	156
OK311500010080_00	Otter Creek	OK311500-01-0080F	16	52
OK311500010050_00	Stinking Creek	OK311500010050G	19	80
OK311500010020_10	North Fork of the Red River, US 62, Headrick	OK311500010020-001AT	19	73
OK311310030050_00	Brush Creek	OK311310030050G	14	98
OK311310030040_00	Little Deep Red Creek	OK311310-03-0040D	17	81
OK311310030010_00	Deep Red Creek	OK311310-03-0010D	15	56
OK311310020010_00	West Cache Creek, SH5B, Taylor	OK311310020010-001AT,OK311310-02-0010M	20	55
OK311310010070_00	Suttle Creek	400265	12	65
OK311300010020_10	East Cache Creek, SH 53, Walters	11300010020-001AT	13	50
OK311300010020_00	Cache Creek, East	OK311300010020-001AT,OKS0104	17	69
OK311200000080_00	Dry Creek	OK311200000080G	16	35
OK311200000060_00	Cow Creek	OK311200-00-0060L	29	69
OK311200000030_00	Beaver Creek	311200000060-01,OK311200-00-0030L	15	52
OK311100040080_00	Mud Creek, Lower West	OK311100040080G	18	94
OK311100040010_00	Mud Creek	OK311100040010-001AT,OK311100-04-0010D	22	82
OK311100010300_00	Fleetwood Creek	OK311100-01-0300D	15	59
OK311100010290_00	Red Creek	OK311100-01-0290D	21	128

2.3 Water Quality Target

The Code of Federal Regulations (40 CFR §130.7(c)(1)) states that, "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards." For the WQM stations requiring bacteria TMDLs in this report, defining the water quality target is somewhat complicated by the use of three different bacterial indicators each with different numeric criterion for determining attainment of PBCR use as defined in the Oklahoma WQSs. An individual water quality target is established for each bacterial indicator since each indicator group must demonstrate compliance with the numeric criteria prescribed in the Oklahoma WQS (OWRB 2008). As previously stated, because available bacteria data were collected on an approximate monthly basis (see Appendix A) instead of at least five samples over a 30–day period, data for these TMDLs are analyzed and presented in relation to both the instantaneous and a long-term geometric mean for each bacterial indicator.

All TMDLs for fecal coliform must take into account that no more than 25 percent of the samples may exceed the instantaneous numeric criteria. For *E. coli* and Enterococci, no samples may exceed the instantaneous criteria. Since the attainability of stream beneficial uses for *E. coli* and Enterococci is based on the compliance of either the instantaneous or a long-term geometric mean criterion, percent reductions goals will be calculated for both criteria. TMDLs will be based on the percent reduction required to meet either the instantaneous or long-term geometric mean criterion, whichever is less.

The water quality target for bacteria will also incorporate an explicit 10 percent MOS. For example, if fecal coliform is utilized to establish the TMDL, then the water quality target is 360 organisms per 100 milliliters (mL), 10 percent lower than the instantaneous water quality criteria (400/100 mL). For *E. coli* the instantaneous water quality target is 365 organisms/100 mL, which is 10 percent lower than the criterion value (406/100 mL), and the geometric mean water quality target is 113 organisms/100 mL, which is 10 percent lower than the criterion value (126/100 mL). For Enterococci the instantaneous water quality target is 97/100 mL, which is 10 percent lower than the criterion value (108/100 mL) and the geometric mean water quality target is 30 organisms/100 mL, which is 10 percent lower than the criterion value (33/100 mL).

The allowable bacteria load is derived by using the actual or estimated flow record multiplied by the water quality target. The line drawn through the allowable load data points is the water quality target which represents the maximum load for any given flow that still satisfies the WQS.

An individual water quality target established for turbidity must demonstrate compliance with the numeric criteria prescribed in the Oklahoma WQS (OWRB 2008). According to the Oklahoma WQS [785:45-5-12(f)(7)], the turbidity criterion for streams with WWAC beneficial use is 50 NTUs (OWRB 2008). The turbidity of 50 NTUs applies only to seasonal base flow conditions. Turbidity levels are expected to be elevated during, and for several days after, a storm event.

TMDLs for turbidity in streams designated as WWAC must take into account that no more than 10 percent of the samples may exceed the numeric criterion of 50 NTU. However, as described above, because turbidity cannot be expressed as a mass load, TSS is used as a surrogate for TMDL development. Since there is no numeric criterion in the Oklahoma WQS for TSS, a specific method must be developed to convert the turbidity criterion to TSS based on a relationship between turbidity and TSS. The method for deriving the relationship between turbidity and TSS and for calculating a water body specific water quality goal using TSS is summarized in Section 4 of this report.

The MOS for the TSS TMDLs varies by waterbody and is related to the goodness-of-fit metrics of the turbidity-TSS regressions. The method for defining MOS percentages is described in Section 5 of this report.

SECTION 3
POLLUTANT SOURCE ASSESSMENT

A pollutant source assessment characterizes known and suspected sources of pollutant loading to impaired waterbodies. Sources within a watershed are categorized and quantified to the extent that information is available. Pathogen indicator bacteria originate from the digestive tract of warm-blooded animals; some plant life and sources may be point or nonpoint in nature. Turbidity may originate from NPDES-permitted facilities, fields, construction sites, quarries, stormwater runoff and eroding stream banks.

Point sources are permitted through the NPDES program. NPDES-permitted facilities that discharge treated wastewater are required to monitor for one of the three bacterial pathogen indicators (fecal coliform, *E coli*, or Enterococci) and TSS in accordance with their permits. Nonpoint sources are diffuse sources that typically cannot be identified as entering a waterbody through a discrete conveyance at a single location. Nonpoint sources may emanate from land activities that contribute bacteria or TSS to surface water as a result of rainfall runoff. For the TMDLs in this report, all sources of pollutant loading not regulated by NPDES are considered nonpoint sources.

The 2008 Integrated Water Quality Assessment Report (ODEQ 2008) listed potential sources of turbidity as clean sediment, grazing in riparian corridors of streams and creeks, highway/road/bridge runoff (non-construction related), non-irrigated crop production, petroleum/natural gas activities, rangeland grazing, as well as other unknown sources. The following discussion describes what is known regarding point and nonpoint sources of bacteria in the impaired watersheds. Where information was available on point and nonpoint sources of indicator bacteria or TSS originating in Texas (Sweetwater Creek, OK311510020120_03), data were provided and summarized as part of each category. These data were provided to demonstrate that some of the indicator bacteria or TSS loading outside of Oklahoma's jurisdiction may contribute to nonsupport of the WWAC use in Oklahoma. It is recognized that Oklahoma has no enforcement authority over TSS sources originating beyond the Oklahoma state boundary.

3.1 NPDES-Permitted Facilities

Under 40 CFR, §122.2, a point source is described as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Certain NPDES-permitted municipal plants are classified as no-discharge facilities. NPDES-permitted facilities classified as point sources that may contribute bacteria or TSS loading include:

- NPDES municipal wastewater treatment plant (WWTP);
- NPDES Industrial WWTP Discharges;
- NPDES municipal no-discharge WWTP;
- NPDES Concentrated Animal Feeding Operation (CAFO);
- NPDES municipal separate storm sewer system (MS4) discharges;
- NPDES multi-sector general permits; and
- NPDES construction stormwater discharges.

Continuous point source discharges such as WWTPs could result in discharge of elevated concentrations of fecal coliform bacteria if the disinfection unit is not properly maintained, is of poor design, or if flow rates are above the disinfection capacity. It is possible that continuous point source discharges from municipal and industrial WWTPs could result in discharge of elevated concentrations of TSS if a facility is not properly maintained, is of poor design, or flow rates exceed capacity. However, in most cases suspended solids discharged by WWTPs consist primarily of organic solids rather than inorganic suspended solids (i.e., soil and sediment particles from erosion or sediment resuspension). Discharges of organic suspended solids from WWTPs are addressed by ODEQ through its permitting of point sources to maintain WQS for dissolved oxygen and are not considered a potential source of turbidity in this TMDL. Discharges of TSS will be considered to be organic suspended solids if the discharge permit includes a limit for BOD or CBOD. Only WWTP discharges of inorganic suspended solids will be considered and will receive wasteload allocations.

While the no-discharge facilities do not discharge wastewater directly to a waterbody, it is possible that the collection systems associated with each facility may be a source of bacteria loading to surface waters. CAFOs are recognized by USEPA as significant sources of pollution, and may have the potential to cause serious impacts to water quality if not properly managed.

Stormwater runoff from MS4 areas, which is now regulated under the USEPA NPDES Program, can also contain high fecal coliform bacteria concentrations. Stormwater runoff from MS4 areas, facilities under multi-sector general permits, and NPDES construction stormwater discharges, which are regulated under the USEPA NPDES Program, can contain TSS concentrations. 40 C.F.R. § 130.2(h) requires that NPDES-regulated stormwater discharges must be addressed by the wasteload allocation component of a TMDL. However, any stormwater discharge by definition occurs during or immediately following periods of rainfall and elevated flow conditions when Oklahoma Water Quality Standard for turbidity does not apply. Oklahoma Water Quality Standards specify that the criteria for turbidity “apply only to seasonal base flow conditions” and go on to say “Elevated turbidity levels may be expected during, and for several days after, a runoff event” [OAC 785:45-5-12(f)(7)]. In other words, the turbidity impairment status is limited to base flow conditions and stormwater discharges from MS4 areas or construction sites do not contribute to the violation of Oklahoma’s turbidity standard. Therefore, WLAs for NPDES-regulated stormwater discharges is essentially considered unnecessary in this TMDL report and will not be included in the TMDL calculations.

There are no NPDES-permitted facilities of any type in the contributing watersheds of Deer Creek (OK311800000070_00), Red Creek (OK311100010290_00) and Fleetwood Creek (OK311100010300_00). The remaining twelve watersheds in the Study Area have at least one NPDES-permitted facility.

3.1.1 Continuous Point Source Dischargers

The locations of the NPDES-permitted facilities that discharge wastewater to surface waters addressed in these TMDLs are listed in Table 3-1 and displayed in Figures 3-1 and 3-2. For some continuous point source discharge facilities the permitted design flow was not available and therefore is not provided in Table 3-1. There are 8 continuous point source discharging facilities within the Study Area but they are not all sources of concern for bacteria or TSS loading. None of these facilities are not discharging to a waterbody that requires a TMDL for bacteria. All of the facilities in Table 3-1 discharge TSS and have specific permit limits for TSS which are provided in Table 3-1. However, the municipal WWTPs designated with a Standard Industrial Code number 4952 or 4959 in Table 3-1 discharge organic TSS and therefore are not considered a potential source of turbidity within their respective watershed. There are two active NPDES-permitted industrial facilities operating in the Study Area which are shown in Figures 3-1 and 3-2 and facility information is listed in Table 3-1.

Only one WWTP dischargers for TSS impaired watersheds were reviewed for availability of DMR data. DMR data for TSS from Meridian Aggregates Company (OKG950015) are provided in Appendix C.

Table 3-1 Point Source Discharges in the Study Area

OPDES Permit No.	Name	Receiving Water (Waterbody ID)	Facility Type	SIC Code	County	Design Flow (mgd)	Facility ID	Expiration Date	Max. FC cfu/100mL	Max./Avg. TSS mg/L
OKG950015	Meridian Aggregates Company	OK311500010080_00	Crushed and Broken Granite	1423	Kiowa	NA	38000240	01/31/13	NA	45
OK0026115	City of Ada	OK311500010050_00	Sewerage Systems	4952	Jackson	3.2	S20626	09/30/09	400/200	45/30
OK0028037	City of Altus (SE WDS)	OK311500010050_00	Sewerage Systems	4952	Jackson	4	S11514	8/31/12	NA	22.5/15
OK0027171	City of Fredrick (East Wastewater Treatment Facility)	OK311310030040_00	Sewerage Systems	4952	Tillman	0.55	S11309	12/31/11	NA	135/90
OK0027189	City of Fredrick (Industrial Park)	OK311310010070_00	Sewerage Systems	4952	Tillman	0.15	S11402	5/31/08	NA	135/90
OK0020770	City of Walters	OK311300010020_10	Sewerage Systems	4952	Cotton	0.33	S11307	7/14/09	NA	135/90
OKG580053	Comache Public Works Authority	OK311200000060_00	Sewerage Systems	4952	Stephens	0.1	S11206	6/30/11	NA	135/90
OKG580033	Town of Ringling	OK311100040010_00	Sewerage Systems	4952	Jefferson	0.22	S11103	6/30/11	NA	135/90

NA = not available.

Figure 3-1 Locations of NPDES-Permitted Facilities in the Study Area

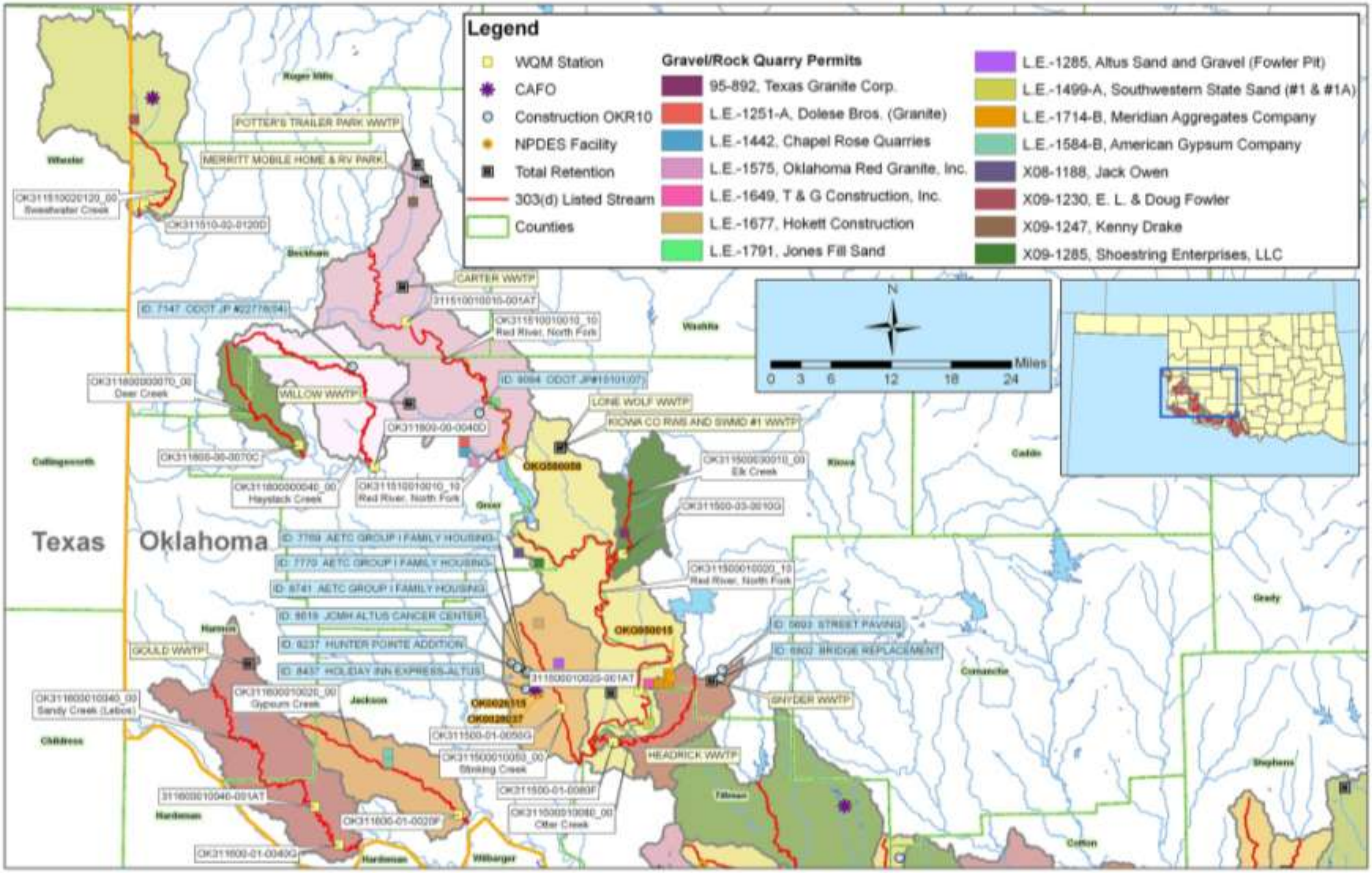
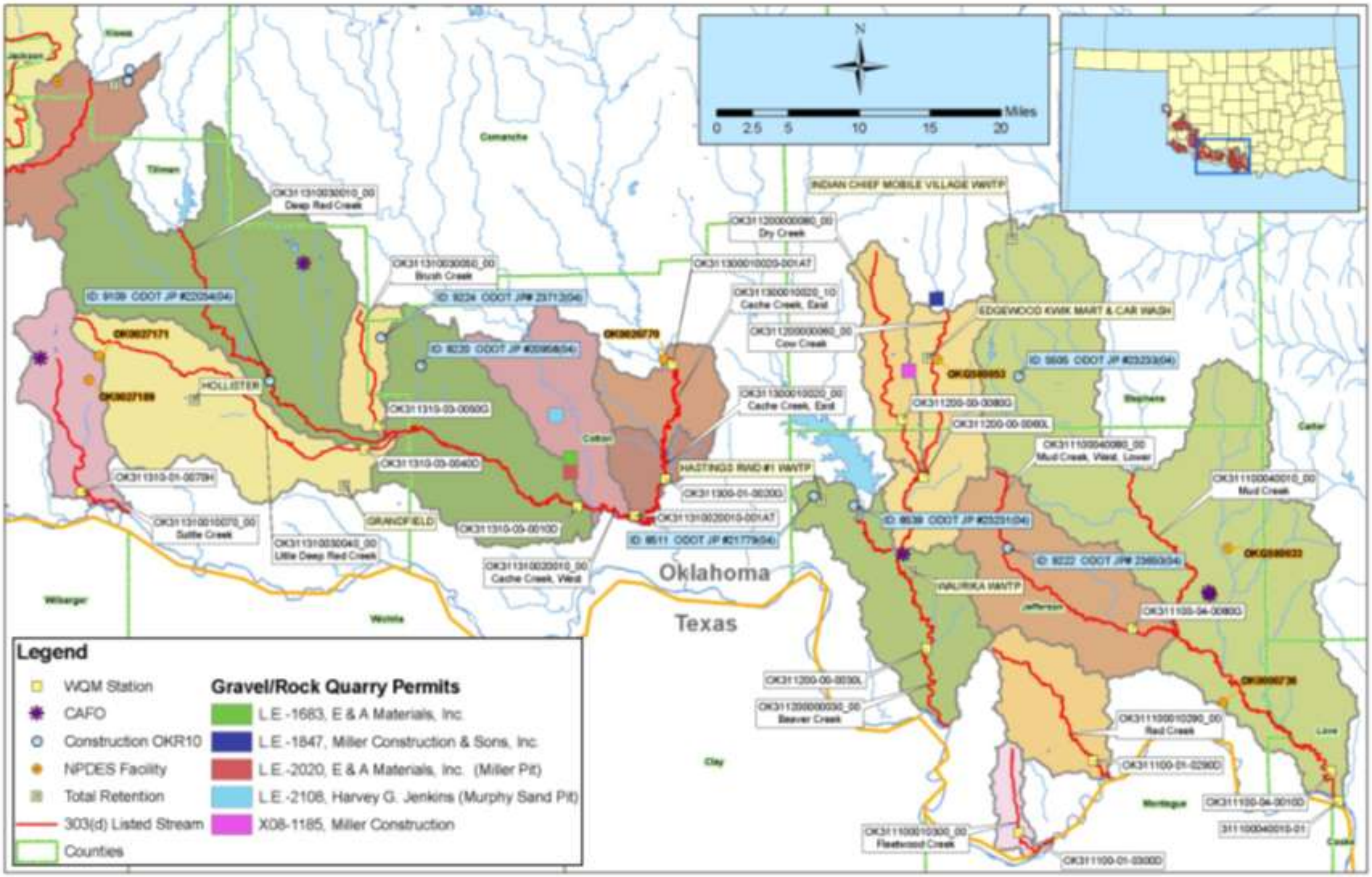


Figure 3-2 Locations of NPDES-Permitted Facilities in the Study Area



3.1.2 NPDES No-Discharge Facilities and Sanitary Sewer Overflows

For the purposes of these TMDLs, it is assumed that no-discharge facilities do not contribute indicator bacteria or TSS loading. However, it is possible the wastewater collection systems associated with these no-discharge facilities could be a source of indicator bacteria loading, or that discharges from the wastewater plant may occur during large rainfall events that exceed the systems' storage capacities. There are 15 municipal or industrial no-discharge facilities in the study area which are listed in Table 3-2. The no-discharge facilities located in Otter Creek (OK311500010080_00), North Fork of the Red River, SH 34, Carter (OK311510010010_10) and Beaver Creek (OK311200000030_00) watersheds could be a contributing to the elevated levels of instream indicator bacteria loading.

Table 3-2 NPDES No-Discharge Facilities in the Study Area

Facility	Facility ID	County	Facility Type	Type	Waterbody ID and Waterbody Name
Gould WWTP	11702	Harmon	Lagoon (total retention)	Municipal	OK311600010040_00, Sandy Creek (Lebos)
Merritt Mobile Home & RV Park	11524	Beckham	Lagoon (total retention)	Municipal	OK311510010010_10, Red River, North Fork, SH 34, Carter
Carter WWTP	11521	Beckham	Lagoon (total retention)	Municipal	OK311510010010_10, Red River, North Fork, SH 34, Carter
Potter's Trailer Park WWTP	11525	Beckham	Lagoon (total retention)	Municipal	OK311510010010_10, Red River, North Fork, SH 34, Carter
Willow WWTP	11802	Greer	Lagoon (total retention)	Municipal	OK311510010010_10, Red River, North Fork, SH 34, Carter
Snyder WWTP	11513	Kiowa	Land Application	Municipal	OK311500010080_00, Otter Creek
Headrick WWTP	11527	Jackson	Lagoon (total retention)	Municipal	OK311500010020_10, Red River, North Fork, U.S. 62, Headrick
Kiowa Co RWS and SWMD #1 WWTP	11532	Kiowa	Lagoon (total retention)	Municipal	OK311500010020_10, Red River, North Fork, U.S. 62, Headrick
Lone Wolf WWTP	11510	Kiowa	Land Application	Municipal	OK311500010020_10, Red River, North Fork, U.S. 62, Headrick
Grandfield	11311	Tillman	Land Application	Municipal	OK311310030040_00, Little Deep Red Creek
Hollister	11310	Tillman	Lagoon (total retention)	Municipal	OK311310030040_00, Little Deep Red Creek
Edgewood Kwik Mart & Car Wash	WD96-012	Stephens	Total retention	Industrial	OK311200000060_00, Cow Creek
Hastings RWD #1 WWTP	11212	Jefferson	Lagoon (total retention)	Municipal	OK311200000030_00, Beaver Creek

Facility	Facility ID	County	Facility Type	Type	Waterbody ID and Waterbody Name
Waurika WWTP	11208	Jefferson	Land Application	Municipal	OK311200000030_00, Beaver Creek
Indian Chief Mobile Village WWTP	11109	Stephens	Lagoon (total retention)	Municipal	OK311100040010_00, Mud Creek

Sanitary sewer overflows (SSO) from wastewater collection systems, although infrequent, can be a major source of indicator bacteria loading to streams. SSOs have existed since the introduction of separate sanitary sewers, and most are caused by blockage of sewer pipes by grease, tree roots, and other debris that clog sewer lines, by sewer line breaks and leaks, cross connections with storm sewers, and inflow and infiltration of groundwater into sanitary sewers. SSOs are permit violations that must be addressed by the responsible NPDES permittee. The reporting of SSOs has been strongly encouraged by USEPA, primarily through enforcement and fines. While not all sewer overflows are reported, ODEQ has data on reported SSOs. No SSOs were reported. Without data it is not possible to quantify the spatial and temporal magnitude of indicator bacteria loading from SSOs in this watershed.

3.1.3 Concentrated Animal Feeding Operations

The Agricultural Environmental Management Services (AEMS) of the Oklahoma Department of Agriculture, Food and Forestry (ODAFF) was created to help develop, coordinate, and oversee environmental policies and programs aimed at protecting the Oklahoma environment from pollutants associated with agricultural animals and their waste. Through regulations established by the Oklahoma Concentrated Animal Feeding Operation Act, AEMS works with producers and concerned citizens to ensure that animal waste does not impact the waters of the state. A CAFO is an animal feeding operation that confines and feeds at least 1,000 animal units for 45 days or more in a 12-month period (ODAFF 2005). The CAFO Act is designed to protect water quality through the use of best management practices (BMP) such as dikes, berms, terraces, ditches, or other similar structures used to isolate animal waste from outside surface drainage, except for a 25-year, 24–hour rainfall event (ODAFF 2005). CAFOs are considered no-discharge facilities.

CAFOs are designated by USEPA as significant sources of pollution, and may have the potential to cause serious impacts to water quality if not managed properly. Potential problems from CAFOs can include unauthorized discharges of bacteria or nutrient loads to waters of the state and failure to properly operate wastewater lagoons. CAFOs are not considered a source of TSS loading. The location of each CAFO is shown in Figure 3-1 and is listed in Table 3-3.

Regulated CAFOs within the watershed operate under NPDES and State permits issued and overseen by EPA and ODAFF. In order to comply with this TMDL, those CAFO permits in the watershed and their associated management plans must be reviewed. Further actions to reduce bacteria loads and achieve progress toward meeting the specified reduction goals must be implemented. This provision will be forwarded to EPA and ODAFF for follow up.

Table 3-3 NPDES-Permitted CAFOs in Study Area

ODAFF Owner ID	EPA Facility	ODAFF ID	ODAFF License Number	Maximum Number of Dairy Heifers Permitted at Facility	Maximum Number of Dairy Cattle Permitted at Facility	Maximum Number of Slaughter Feeder Cattle Permitted at Facility	Total # of Animal Units at Facility	County	Waterbody ID and Waterbody Name
WQ0000070	OKG010063	174	62			3,000	3,000	Jackson	OK311500010050_00, Stinking Creek
AGN031396	OKG010027	64	1478			2,999	2,999	Tillman	OK311310030010_00, Deep Red Creek
WQ0000325	OKU000455	397	200002	360	2,400		3,720	Tillman	OK311310010070_00, Suttle Creek
AGR008527	OKG010286	306	1415			1,100	1,100	Jefferson	OK311200000030_00, Beaver Creek
AGN007242	OKG010083	315	98			1,800	1,800	Jefferson	OK311100040010_00, Mud Creek

3.1.4 Stormwater Permits Construction Activities

A general stormwater permit (OKR10) is required for any stormwater discharges associated with construction activities that result in land disturbance of equal to or greater than one (1) acre, or less than one (1) acre if they are part of a larger common plan of development or sale that totals at least one (1) acre. The permit also authorizes any stormwater discharges from support activities (e.g. concrete or asphalt batch plants, equipment staging yards, material storage areas, excavated material disposal areas, and borrow areas) that are directly related to a construction site that is required to have permit coverage, and is not a commercial operation serving unrelated different sites (ODEQ 2007). Stormwater discharges occur only during or immediately following periods of rainfall and elevated flow conditions when the turbidity criteria do not apply and are not considered potential contributors to turbidity impairment. The construction permits are summarized in Table 3-4.

3.1.5 Rock, Sand and Gravel Quarries

Operators of rock, sand and gravel quarries in Oklahoma are regulated with a general permit (OKG950000). The general permit does not allow discharge of wastewater to waterbodies included in Oklahoma's 303(d) List of impaired water bodies listed for turbidity for which a TMDL has not been performed or the result of the TMDL indicates that discharge limits more stringent than 45 mg/l for TSS are required (ODEQ 2009). Table 3-5 summarizes data from the Oklahoma Department of Mines and provides the permitted mining acres for each of the quarries located within the Study Area. The locations of these quarries are shown in Figure 3-1.

Table 3-4 Construction Permits Summary

Company Name	County	Permit ID	Date Issued	Waterbody ID	Receiving Water (Permit)	Estimated Acres
ODOT JP #22778(04)	Greer	7147	1/11/2008	OK311800000040_00	Tributary to Haystack Creek	1.92
ODOT JP#10101(07)	Greer/Kiowa	9094	6/11/2008	OK311510010010_10	North Fork of the Red River	97
Bridge Replacement	Kiowa	6802	3/5/2008	OK311500010080_00	Otter Creek	1
Street Paving	Kiowa	5693	3/31/2008	OK311500010080_00	Unnamed tributary to Otter Creek	1
JCMH Altus Cancer Center	Jackson	8619	12/17/2007	OK311500010050_00	Unnamed tributary to Stinking Creek	1.5
Hunter Pointe Addition	Jackson	8237	9/27/2007	OK311500010050_00	Unnamed tributary to Stinking Creek	5.21
AETC Group I Family Housing	Jackson	7769	3/5/2008	OK311500010050_00	Unnamed tributary to Stinking Creek	26
AETC Group I Family Housing	Jackson	7770	3/5/2008	OK311500010050_00	Unnamed tributary to Stinking Creek	23
Holiday Inn Express-Altus	Jackson	8437	10/30/2007	OK311500010050_00	Unnamed tributary to Stinking Creek	2.18
AETC Group I Family Housing	Jackson	8741	1/19/2008	OK311500010050_00	Unnamed tributary to Stinking Creek	7
ODOT JP# 23712(04)	Cotton	9224		OK311310030050_00	Unnamed tributary to Brush Creek	2
ODOT JP #22034(04)	Tillman	9109	5/23/2008	OK311310030010_00	Deep Red Creek	2.69
ODOT JP #20958(04)	Cotton	8220	10/24/2007	OK311310030010_00	Dry Red Creek	15
ODOT JP #21779(04)	Jefferson	8511	12/17/2007	OK311200000030_00	Unnamed tributary to Waurika Lake	4
ODOT JP #23231(04)	Jefferson	8539	11/20/2007	OK311200000030_00	Beaver Creek	19
ODOT JP# 23650(04)	Jefferson	9222		OK311100040080_00	West Mud Creek	2
ODOT JP #23233(04)	Stephens	5505	2/11/2008	OK311100040010_00	Deer Creek tributary to Mud Creek	17

Table 3-5 Rock, Sand and Gravel Quarries

Company Name	County	Permit ID	Product	Permitted Acres	Permit Issue Date	Permit Renewal Date	Mining Expiration Date	Waterbody ID
American Gypsum Company (Gilbreath Property)	Jackson	L.E.-1584-B	Gypsum	1460	8/1/1997	7/31/2008	7-31-2025	OK311600010020_00
American Gypsum Company (Gilbreath Property)	Jackson	L.E.-1584-B	Gypsum	1460	8/1/1997	7/31/2008	7-31-2025	OK311600010020_00
E. L. & Doug Fowler	Roger Mill	X09-1230	Red Shale	3	3/1/2008		2-28-09	OK311510020120_00
Kenny Drake	Beckham	X09-1247	Red Shale	3	3/1/2008		2-28-09	OK311510010010_10
Dolese Bros. (Granite)	Greer	L.E.-1251-A	Limestone	65	12/1/1993	11/30/2008	11-30-2018	OK311510010010_10
Chapel Rose Quarries	Greer	L.E.-1442	Granite	23	12/1/2000	11/30/2008	Life of Mine	OK311510010010_10
Oklahoma Red Granite, Inc.	Greer	L.E.-1575	Granite	90	5/1/1997	4/30/2009	4-30-2022	OK311510010010_10
Jones Fill Sand	Kiowa	L.E.-1791	Sand & Gravel	10	4/1/2004	3/31/2009	3-31-2019	OK311510010010_10
Texas Granite Corp.	Kiowa	95-892	Granite	2	4/1/2008		3-31-09	OK311500030010_00
Meridian Aggregates Company, a Limited Partnership (Snyder Quarry)	Kiowa	L.E.-1714-B	Granite	311	11/1/2007		10-31-08	OK311500010080_00
Meridian Aggregates Company, a Limited Partnership (Snyder Quarry)	Kiowa	L.E.-1714-B	Granite	311	11/1/2007		10-31-08	OK311500010080_00
Meridian Aggregates Company, a Limited Partnership (Snyder Quarry)	Kiowa	L.E.-1714-B	Granite	311	11/1/2007		10-31-08	OK311500010080_00
Hokett Construction	Jackson	L.E.-1677	Sand	80	4/1/1998	3/31/2009	3-31-2018	OK311500010050_00
Altus Sand and Gravel (Fowler Pit)	Jackson	L.E.-1285	Sand & Gravel	5	3/1/1999	2/28/2009	2-28-2009	OK311500010050_00
Meridian Aggregates Company, a Limited Partnership (Snyder Quarry)	Kiowa	L.E.-1714-B	Granite	311	11/1/2007		10-31-08	OK311500010020_10
Meridian Aggregates Company, a Limited Partnership (Snyder Quarry)	Kiowa	L.E.-1714-B	Granite	311	11/1/2007		10-31-08	OK311500010020_10

Company Name	County	Permit ID	Product	Permitted Acres	Permit Issue Date	Permit Renewal Date	Mining Expiration Date	Waterbody ID
Meridian Aggregates Company, a Limited Partnership (Snyder Quarry)	Kiowa	L.E.-1714-B	Granite	311	11/1/2007		10-31-08	OK311500010020_10
Shoestring Enterprises, LLC	Jackson	X09-1285	Fill Sand	3	6/1/2008		5-31-09	OK311500010020_10
T & G Construction, Inc.	Kiowa	L.E.-1649	Sand & Gravel	20	10/1/2003	9/30/2008	9-30-2008	OK311500010020_10
Southwestern State Sand (#1 & #1A)	Tillman	L.E.-1499-A	Sand & Gravel	204	10/1/1996	9/30/2008	9-30-2052	OK311500010020_10
Jack Owen	Greer	X08-1188	Sand	4	11/5/2007		11-4-08	OK311500010020_10
E & A Materials, Inc.	Cotton	L.E.-1683	Sand & Gravel	150	12/1/1998	11/30/2008	11-30-13	OK311310030010_00
E & A Materials, Inc. (Miller Pit)	Cotton	L.E.-2020	Sand & Gravel	121	5/1/2004	4/30/2009	4-30-2019	OK311310030010_00
Harvey G. Jenkins (Murphy Sand Pit)	Cotton	L.E.-2108	Sand	10	12/1/2005	11/30/2008	11-30-2010	OK311310020010_00
E & A Materials, Inc.	Cotton	L.E.-1683	Sand & Gravel	150	12/1/1998	11/30/2008	11-30-13	OK311310020010_00
E & A Materials, Inc. (Miller Pit)	Cotton	L.E.-2020	Sand & Gravel	121	5/1/2004	4/30/2009	4-30-2019	OK311310020010_00
Miller Construction	Stephens	X08-1185	Sand	3	12/1/2007		11-30-08	OK311200000080_00
Miller Construction	Stephens	X08-1185	Sand	3	12/1/2007		11-30-08	OK311200000060_00
Miller Construction & Sons, Inc.	Stephens	L.E.-1847	Sand & Fill	20	12/1/2001	11/30/2008	11-30-2011	OK311200000060_00

3.2 Nonpoint Sources

Nonpoint sources include those sources that cannot be identified as entering the waterbody at a specific location. The relatively homogeneous land use/land cover categories throughout the Study Area associated with rural agricultural, forest and range management activities has an influence on the origin and pathways of pollutant sources to surface water. Pathogen indicator bacteria originate from warm-blooded animals in rural, suburban, and urban areas. These sources include wildlife, various agricultural activities and domesticated animals, land application fields, urban runoff, failing onsite wastewater disposal (OSWD) systems and domestic pets. Water quality data collected from streams draining urban communities often show existing concentrations of fecal coliform bacteria at levels greater than a state's instantaneous standards. A study under USEPA's National Urban Runoff Project indicated that the average fecal coliform concentration from 14 watersheds in different areas within the United States was approximately 15,000/100 mL in stormwater runoff (USEPA 1983). Runoff from urban areas not permitted under the MS4 program can be a significant source of fecal coliform bacteria. Water quality data collected from streams draining many of the non-permitted communities show existing loads of fecal coliform bacteria at levels greater than the State's instantaneous standards.

Various potential nonpoint sources of TSS as indicated in the 2008 Integrated Report include sediments originating from grazing in riparian corridors of streams and creeks, highway/road/bridge runoff,non-irrigated crop production, rangeland grazing and other sources of sediment loading (ODEQ 2008). Elevated turbidity measurements can be caused by stream bank erosion processes, stormwater runoff events and other channel disturbances. The following section provides general information on nonpoint sources contributing bacteria or TSS loading within the Study Area.

3.2.1 Wildlife

Fecal coliform bacteria are produced by all warm-blooded animals, including wildlife such as mammals and birds. In developing bacteria TMDLs it is important to identify the potential for bacteria contributions from wildlife by watershed. Wildlife is naturally attracted to riparian corridors of streams and rivers. With direct access to the stream channel, wildlife can be a concentrated source of bacteria loading to a waterbody. Fecal coliform bacteria from wildlife are also deposited onto land surfaces, where it may be washed into nearby streams by rainfall runoff. Currently there are insufficient data available to estimate populations of wildlife and avian species by watershed. Consequently it is difficult to assess the magnitude of bacteria contributions from wildlife species as a general category.

However, adequate data are available by county to estimate the number of deer by watershed. This report assumes that deer habitat includes forests, croplands, and pastures. Using Oklahoma Department of Wildlife and Conservation county data, the population of deer can be roughly estimated from the actual number of deer harvested and harvest rate estimates. Because harvest success varies from year to year based on weather and other factors, the average harvest from 1999 to 2003 was combined with an estimated annual harvest rate of 20 percent to predict deer population by county. Using the estimated deer population by county and the percentage of the watershed area within each county, a wild deer population can be calculated for each watershed.

According to a study conducted by the American Society of Agricultural Engineers (ASAE), deer release approximately $5x10^8$ fecal coliform units per animal per day (ASAE 1999). Although only a fraction of the total fecal coliform loading produced by the deer population may actually enter a waterbody, the estimated fecal coliform production based on the estimated deer population provided in Table 3-6 in cfu/day provides a relative magnitude of loading in each watershed.

Table 3-6 Estimated Population and Fecal Coliform Production for Deer

Waterbody ID	Waterbody Name	Watershed Area (acres)	Wild Deer Population	Estimated Wild Deer per acre	Fecal Production (x 10^8 cfu/day) of Deer Population
OK311800000070_00	Deer Creek	29,565	150	0.005	748
OK311800000040_00	Haystack Creek	85,819	446	0.005	2,229
OK311600010040_00	Sandy Creek (Lebos)	118,173	528	0.004	2,641
OK311600010020_00	Gypsum Creek	66,593	293	0.004	1,463
OK311510020120_00	Sweetwater Creek	123,647	339	0.003	1,695
OK311510010010_10	North Fork of the Red River, SH 34, Carter	174,679	799	0.005	3,993
OK311500030010_00	Elk Creek, SH 19, Roosevelt	40,009	104	0.003	521
OK311500010080_00	Otter Creek	44,692	471	0.011	2,356
OK311500010050_00	Stinking Creek	78,932	346	0.004	1,732
OK311500010020_10	North Fork of the Red River, US 62, Headrick	170,458	569	0.003	2,844
OK311310030050_00	Brush Creek	17,734	54	0.003	270
OK311310030040_00	Little Deep Red Creek	91,181	269	0.003	1,343
OK311310030010_00	Deep Red Creek	247,447	765	0.003	3,824
OK311310020010_00	West Cache Creek, SH5B, Taylor	48,811	165	0.003	827
OK311310010070_00	Suttle Creek	40,980	121	0.003	604
OK311300010020_10	East Cache Creek, SH 53, Walters	28,570	101	0.004	505
OK311300010020_00	Cache Creek, East	17,421	62	0.004	308
OK311200000080_00	Dry Creek	31,456	157	0.005	784
OK311200000060_00	Cow Creek	54,616	217	0.004	1,085
OK311200000030_00	Beaver Creek	68,612	175	0.003	873
OK311100040080_00	Mud Creek, Lower West	79,183	202	0.003	1,008
OK311100040010_00	Mud Creek	284,371	1,273	0.004	6,364
OK311100010300_00	Fleetwood Creek	10,545	27	0.003	133
OK311100010290_00	Red Creek	40,444	103	0.003	515

3.2.2 Non-Permitted Agricultural Activities and Domesticated Animals

There are a number of non-permitted agricultural activities that can also be sources of bacteria or TSS loading. Agricultural activities of greatest concern are typically those associated with livestock operations (Drapcho and Hubbs 2002). Examples of commercially raised farm animal activities that can contribute to bacteria sources include:

Processed commercially raised farm animal manure is often applied to fields as fertilizer, and can contribute to fecal bacteria loading to waterbodies if washed into streams by runoff.

Animal grazing in pastures deposit manure containing fecal bacteria onto land surfaces. These bacteria may be washed into waterbodies by runoff.

Animal often have direct access to waterbodies and can provide a concentrated source of fecal bacteria loading directly into streams or can cause unstable stream banks which can contribute TSS.

Table 3-7 provides estimated numbers of selected livestock by watershed based on the 2002 U.S. Department of Agriculture (USDA) county agricultural census data (USDA 2002). The estimated commercially raised farm animal populations in Table 3-7 were derived by using the percentage of the watershed within each county. Because the watersheds are generally much smaller than the counties, and commercially raised farm animals are not evenly distributed across counties or constant with time, these are rough estimates only. Cattle are clearly the most abundant species of commercially raised farm animals in the Study Area and often have direct access to the impaired waterbodies or their tributaries.

Detailed information is not available to describe or quantify the relationship between instream concentrations of bacteria and land application of manure from commercially raised farm animal. Nor is sufficient information available to describe or quantify the contributions of sediment loading caused by commercially raised farm animal responsible for destabilizing stream banks or erosion in pasture fields. The estimated acreage by watershed where manure was applied in 2002 is shown in Table 3-7. These estimates are also based on the county level reports from the 2002 USDA county agricultural census, and thus, represent approximations of the commercially raised farm animal populations in each watershed. Despite the lack of specific data, for the purpose of these TMDLs, land application of commercially raised farm animal manure is considered a potential source of bacteria loading to the watersheds in the Study Area.

According to a livestock study conducted by the ASAE, the daily fecal coliform production rates by livestock species were estimated as follows (ASAE 1999):

Beef cattle release approximately 1.04E+11 fecal coliform counts per animal per day;

Dairy cattle release approximately 1.01E+11 per animal per day

Swine release approximately 1.08E+10 per animal per day

Chickens release approximately 1.36E+08 per animal per day

Sheep release approximately 1.20E+10 per animal per day

Horses release approximately 4.20E+08 per animal per day;

Turkey release approximately 9.30E+07 per animal per day

Ducks release approximately 2.43E+09 per animal per day

Geese release approximately 4.90E+10 per animal per day

Using the estimated animal populations and the fecal coliform production rates from ASAE, an estimate of fecal coliform production from each group of commercially raised farm animal was calculated in each watershed of the Study Area in Table 3-8. Note that only a small fraction of these fecal coliform are expected to represent loading into waterbodies, either washed into streams by runoff or by direct deposition from wading animals. Cattle again appear to represent the most likely commercially raised farm animal source of fecal bacteria.

Table 3-7 Livestock and Manure Estimates by Watershed

Waterbody ID	Waterbody Name	Cattle & Calves	Dairy Cows	Horses & Ponies	Sheep & Lambs	Hogs & Pigs	Ducks & Geese	Chickens & Turkeys	Acres of Manure Application
OK311800000070_00	Deer Creek	1,147	10	2,581	22	16	2	12	18
OK311800000040_00	Haystack Creek	3,241	23	7,049	58	46	8	34	34
OK311600010040_00	Sandy Creek (Lebos)	0	0	10,728	63	293	4	26	542
OK311600010020_00	Gypsum Creek	0	0	5,918	91	46	6	38	201
OK311510020120_00	Sweetwater Creek	5,383	51	15,113	37	33	1	62	148
OK311510010010_10	North Fork of the Red River, SH 34, Carter	17,462	78	271	219	98	6	79	270
OK311500030010_00	Elk Creek, SH 19, Roosevelt	1,331	3	4,290	140	24	0	4	188
OK311500010080_00	Otter Creek	5,818	245	18,605	494	91	5	56	682
OK311500010050_00	Stinking Creek	0	0	7,004	112	45	8	47	229
OK311500010020_10	North Fork of the Red River, US 62, Headrick	3,640	94	16,850	414	95	7	55	624
OK311310030050_00	Brush Creek	533	85	1,984	5	4	1	13	14
OK311310030040_00	Little Deep Red Creek	2,551	638	8,674	0	12	6	60	95
OK311310030010_00	Deep Red Creek	7,393	1,073	28,900	72	52	12	170	168
OK311310020010_00	West Cache Creek, SH5B, Taylor	1,558	1	7,579	30	15	0	29	0
OK311310010070_00	Suttle Creek	1,146	287	3,899	0	6	3	27	42
OK311300010020_10	East Cache Creek, SH 53, Walters	4,621	1	36	19	9	0	18	0
OK311300010020_00	Cache Creek, East	2,817	1	22	11	6	0	11	0
OK311200000080_00	Dry Creek	1,644	12	4,478	35	23	20	102	25
OK311200000060_00	Cow Creek	2,674	13	8,599	36	30	21	119	25
OK311200000030_00	Beaver Creek	3,038	1	12,258	0	20	0	46	0
OK311100040080_00	Mud Creek, Lower West	3,507	1	14,147	0	23	0	53	0
OK311100040010_00	Mud Creek	13,908	52	43,307	163	152	119	642	634
OK311100010300_00	Fleetwood Creek	469	0	1,879	0	3	0	7	0
OK311100010290_00	Red Creek	1,791	1	7,226	0	12	0	27	0

Table 3-8 Fecal Coliform Production Estimates for Commercially Raised Farm Animals ($x10^9$ number/day)

Waterbody ID	Waterbody Name	Cattle & Calves-all	Dairy Cows	Horses & Ponies	Goats	Sheep & Lambs	Hogs & Pigs	Ducks & Geese	Chickens & Turkeys	Total
OK311800000070_00	Deer Creek	11,930	104	108	N/A	27	29	6	0	12,204
OK311800000040_00	Haystack Creek	33,708	231	296	N/A	70	82	20	0	34,408
OK311600010040_00	Sandy Creek (Lebos)	0	0	451	N/A	75	527	11	0	1,064
OK311600010020_00	Gypsum Creek	0	0	249	N/A	109	83	16	0	457
OK311510020120_00	Sweetwater Creek	55,983	515	635	N/A	44	60	3	1	57,241
OK311510010010_10	North Fork of the Red River, SH 34, Carter	181,600	786	11	N/A	262	177	15	1	182,852
OK311500030010_00	Elk Creek, SH 19, Roosevelt	13,847	35	180	N/A	168	43	0	0	14,273
OK311500010080_00	Otter Creek	60,510	2,478	781	N/A	593	163	13	1	64,539
OK311500010050_00	Stinking Creek	0	0	294	N/A	135	81	20	1	530
OK311500010020_10	North Fork of the Red River, US 62, Headrick	37,860	947	708	N/A	497	170	19	1	40,202
OK311310030050_00	Brush Creek	5,541	857	83	N/A	6	6	3	0	6,498
OK311310030040_00	Little Deep Red Creek	26,528	6,442	364	N/A	0	22	15	1	33,372
OK311310030010_00	Deep Red Creek	76,889	10,841	1,214	N/A	87	93	32	2	89,157
OK311310020010_00	West Cache Creek, SH5B, Taylor	16,205	15	318	N/A	37	28	0	0	16,603
OK311310010070_00	Suttle Creek	11,923	2,895	164	N/A	0	10	7	0	14,998
OK311300010020_10	East Cache Creek, SH 53, Walters	48,059	9	2	N/A	22	17	0	0	48,110
OK311300010020_00	Cache Creek, East	29,297	6	1	N/A	14	10	0	0	29,327
OK311200000080_00	Dry Creek	17,100	125	188	N/A	42	42	52	1	17,551
OK311200000060_00	Cow Creek	27,805	130	361	N/A	43	54	53	1	28,447
OK311200000030_00	Beaver Creek	31,599	10	515	N/A	0	35	0	1	32,159
OK311100040080_00	Mud Creek, Lower West	36,468	11	594	N/A	0	41	0	1	37,115
OK311100040010_00	Mud Creek	144,642	525	1,819	N/A	195	274	305	7	147,767
OK311100010300_00	Fleetwood Creek	4,875	3	79	N/A	0	5	0	0	4,963
OK311100010290_00	Red Creek	18,627	6	303	N/A	0	21	0	0	18,957

3.2.3 Failing Onsite Wastewater Disposal Systems and Illicit Discharges

ODEQ is responsible for implementing the regulations of Title 252, Chapter 641 of the Oklahoma Administrative Code, which defines design standards for individual and small public onsite sewage disposal systems (ODEQ 2004). OSWD systems and illicit discharges can be a source of bacteria loading to streams and rivers. Bacteria loading from failing OSWD systems can be transported to streams in a variety of ways, including runoff from surface ponding or through groundwater. Fecal coliform-contaminated groundwater discharges to creeks through springs and seeps.

To estimate the potential magnitude of OSWDs fecal bacteria loading, the number of OSWD systems was estimated for each watershed. The estimate of OSWD systems was derived by using data from the 1990 U.S. Census (U.S. Census Bureau 2000). The density of OSWD systems within each watershed was estimated by dividing the number of OSWD systems in each census block by the number of acres in each census block. This density was then applied to the number of acres of each census block within a WQM station watershed. Census blocks crossing a watershed boundary required additional calculation to estimate the number of OSWD systems based on the proportion of the census tracking falling within each watershed. This step involved adding all OSWD systems for each whole or partial census block.

Over time, most OSWD systems operating at full capacity will fail. OSWD system failures are proportional to the adequacy of a state's minimum design criteria (Hall 2002). The 1995 American Housing Survey conducted by the U.S. Census Bureau estimates that, nationwide, 10 percent of occupied homes with OSWD systems experience malfunctions during the year (U.S. Census Bureau 1995). A study conducted by Reed, Stowe & Yanke, LLC (2001) reported that approximately 12 percent of the OSWD systems in east Texas and 8 percent in the Texas Panhandle were chronically malfunctioning. Most studies estimate that the minimum lot size necessary to ensure against contamination is roughly one-half to one acre (Hall 2002). Some studies, however, found that lot sizes in this range or even larger could still cause contamination of ground or surface water (University of Florida 1987). It is estimated that areas with more than 40 OSWD systems per square mile (6.25 septic systems per 100 acres) can be considered to have potential contamination problems (Canter and Knox 1986). Table 3-9 summarizes estimates of sewered and unsewered households for each watershed in the Study Area.

Table 3-9 Estimates of Sewered and Unsewered Households

Waterbody ID	Waterbody Name	Public Sewer	Septic Tank	Other Means	Housing Units	% Sewered
OK311800000070_00	Deer Creek	87	45	2	134	65%
OK311800000040_00	Haystack Creek	361	163	5	529	68%
OK311600010040_00	Sandy Creek (Lebos)	222	136	1	359	62%
OK311600010020_00	Gypsum Creek	181	82	0	263	69%
OK311510020120_00	Sweetwater Creek	170	253	12	435	39%
OK311510010010_10	North Fork of the Red River, SH 34, Carter	1,062	510	6	1,578	67%
OK311500030010_00	Elk Creek, SH 19, Roosevelt	366	75	4	445	82%
OK311500010080_00	Otter Creek	966	348	10	1,324	73%
OK311500010050_00	Stinking Creek	5,001	370	12	5,383	93%
OK311500010020_10	North Fork of the Red River, US 62, Headrick	603	506	6	1,115	54%
OK311310030050_00	Brush Creek	84	36	2	122	69%
OK311310030040_00	Little Deep Red Creek	729	125	3	857	85%
OK311310030010_00	Deep Red Creek	1,062	439	28	1,529	69%
OK311310020010_00	West Cache Creek, SH5B, Taylor	305	111	11	427	71%
OK311310010070_00	Suttle Creek	1,538	79	0	1,617	95%
OK311300010020_10	East Cache Creek, SH 53, Walters	191	64	6	260	73%
OK311300010020_00	Cache Creek, East	115	30	1	146	79%
OK311200000080_00	Dry Creek	312	308	6	626	50%
OK311200000060_00	Cow Creek	447	265	8	720	62%
OK311200000030_00	Beaver Creek	420	121	9	550	76%
OK311100040080_00	Mud Creek, Lower West	395	131	11	537	74%
OK311100040010_00	Mud Creek	1,775	1,396	88	3,259	54%
OK311100010300_00	Fleetwood Creek	39	15	0	54	72%
OK311100010290_00	Red Creek	151	58	1	210	72%

For the purpose of estimating fecal coliform loading in watersheds, an OSWD failure rate of 8 percent was used in the calculations made to characterize fecal coliform loads in each watershed.

Fecal coliform loads were estimated using the following equation (USEPA 2001):

$$\#\frac{counts}{day} = \left(\#Failing\_systems\right) \times \left(\frac{10^6\,counts}{100ml}\right) \times \left(\frac{70gal}{personday}\right) \times \left(\#\frac{person}{household}\right) \times \left(3785.2\frac{ml}{gal}\right)$$

The average of number of people per household was calculated to be 2.44 for counties in the Study Area (U.S. Census Bureau 2000). Approximately 70 gallons of wastewater were estimated to be produced on average per person per day (Metcalf and Eddy 1991). The fecal coliform concentration in septic tank effluent was estimated to be 10^6 per 100 mL of effluent based on reported concentrations from a number of publications (Metcalf and Eddy 1991; Canter and Knox 1985; Cogger and Carlile 1984). Using this information, the estimated load from failing septic systems within the watersheds was summarized below in Table 3-10.

Table 3-10 Estimated Fecal Coliform Load from OSWD Systems

Waterbody ID	Waterbody Name	Acres	Septic Tank	# of Failing Septic Tanks	Estimated Loads from Septic Tanks (x 10^9 counts/day)
OK311800000070_00	Deer Creek	29,565	45	4	23
OK311800000040_00	Haystack Creek	85,819	163	13	84
OK311600010040_00	Sandy Creek (Lebos)	118,173	136	11	70
OK311600010020_00	Gypsum Creek	66,593	82	7	42
OK311510020120_00	Sweetwater Creek	123,647	253	20	131
OK311510010010_10	North Fork of the Red River, SH 34, Carter	174,679	510	41	264
OK311500030010_00	Elk Creek, SH 19, Roosevelt	40,009	75	6	39
OK311500010080_00	Otter Creek	44,692	348	28	180
OK311500010050_00	Stinking Creek	78,932	370	30	191
OK311500010020_10	North Fork of the Red River, US 62, Headrick	170,458	506	40	262
OK311310030050_00	Brush Creek	17,734	36	3	19
OK311310030040_00	Little Deep Red Creek	91,181	125	10	65
OK311310030010_00	Deep Red Creek	247,447	439	35	227
OK311310020010_00	West Cache Creek, SH5B, Taylor	48,811	111	9	57
OK311310010070_00	Suttle Creek	40,980	79	6	41
OK311300010020_10	East Cache Creek, SH 53, Walters	28,570	64	5	33
OK311300010020_00	Cache Creek, East	17,421	30	2	15
OK311200000080_00	Dry Creek	31,456	308	25	159
OK311200000060_00	Cow Creek	54,616	265	21	137
OK311200000030_00	Beaver Creek	68,612	121	10	63
OK311100040080_00	Mud Creek, Lower West	79,183	131	10	68
OK311100040010_00	Mud Creek	284,371	1,396	112	722
OK311100010300_00	Fleetwood Creek	10,545	15	1	8
OK311100010290_00	Red Creek	40,444	58	5	30

3.2.4 Domestic Pets

Fecal matter from dogs and cats, which is transported to streams by runoff from urban and suburban areas, can be a potential source of bacteria loading. On average 37.2 percent of the nation's households own dogs and 32.4 percent own cats and in these households the average number of dogs is 1.7 and 2.2 cats per household (American Veterinary Medical Association 2007). Using the U.S. Census data at the block level (U.S. Census Bureau 2000), dog and cat populations can be estimated for each watershed. Table 3-11 summarizes the estimated number of dogs and cats for the watersheds of the Study Area.

Table 3-11 Estimated Numbers of Pets

Waterbody ID	Waterbody Name	Dogs	Cats
OK311800000070_00	Deer Creek	44	50
OK311800000040_00	Haystack Creek	170	192
OK311600010040_00	Sandy Creek (Lebos)	131	147
OK311600010020_00	Gypsum Creek	155	175
OK311510020120_00	Sweetwater Creek	106	120
OK311510010010_10	North Fork of the Red River, SH 34, Carter	706	797
OK311500030010_00	Elk Creek, SH 19, Roosevelt	158	179
OK311500010080_00	Otter Creek	565	637
OK311500010050_00	Stinking Creek	3665	4135
OK311500010020_10	North Fork of the Red River, US 62, Headrick	527	594
OK311310030050_00	Brush Creek	45	51
OK311310030040_00	Little Deep Red Creek	612	690
OK311310030010_00	Deep Red Creek	592	668
OK311310020010_00	West Cache Creek, SH5B, Taylor	75	85
OK311310010070_00	Suttle Creek	666	751
OK311300010020_10	East Cache Creek, SH 53, Walters	534	603
OK311300010020_00	Cache Creek, East	60	68
OK311200000080_00	Dry Creek	270	305
OK311200000060_00	Cow Creek	705	796
OK311200000030_00	Beaver Creek	632	713
OK311100040080_00	Mud Creek, Lower West	54	60
OK311100040010_00	Mud Creek	1215	1371
OK311100010300_00	Fleetwood Creek	30	34
OK311100010290_00	Red Creek	34	38

Table 3-12 provides an estimate of the fecal coliform load from pets. These estimates are based on estimated fecal coliform production rates of 5.4×10^8 per day for cats and 3.3×10^9 per day for dogs (Schueler 2000).

Table 3-12 Estimated Fecal Coliform Daily Production by Pets (x10^9 counts/day)

Waterbody ID	Waterbody Name	Dogs	Cats	Total
OK311800000070_00	Deer Creek	146	27	173
OK311800000040_00	Haystack Creek	561	103	664
OK311600010040_00	Sandy Creek (Lebos)	431	80	511
OK311600010020_00	Gypsum Creek	512	95	607
OK311510020120_00	Sweetwater Creek	350	65	415
OK311510010010_10	North Fork of the Red River, SH 34, Carter	2,331	430	2,761
OK311500030010_00	Elk Creek, SH 19, Roosevelt	522	96	619
OK311500010080_00	Otter Creek	1,865	344	2,209
OK311500010050_00	Stinking Creek	12,094	2,233	14,327
OK311500010020_10	North Fork of the Red River, US 62, Headrick	1,738	321	2,059
OK311310030050_00	Brush Creek	148	27	176
OK311310030040_00	Little Deep Red Creek	2,018	373	2,391
OK311310030010_00	Deep Red Creek	1,953	361	2,313
OK311310020010_00	West Cache Creek, SH5B, Taylor	249	46	294
OK311310010070_00	Suttle Creek	2,197	406	2,603
OK311300010020_10	East Cache Creek, SH 53, Walters	1,764	326	2,089
OK311300010020_00	Cache Creek, East	199	37	235
OK311200000080_00	Dry Creek	893	165	1,057
OK311200000060_00	Cow Creek	2,328	430	2,757
OK311200000030_00	Beaver Creek	2,086	385	2,471
OK311100040080_00	Mud Creek, Lower West	177	33	210
OK311100040010_00	Mud Creek	4,010	740	4,751
OK311100010300_00	Fleetwood Creek	99	18	118
OK311100010290_00	Red Creek	111	20	131

3.3 Summary of Bacteria Sources

There are no continuous, permitted point sources of bacteria in the Haystack Creek, Stinking Creek, Gypsum Creek, Sweetwater Creek, Otter Creek, Deep Red Creek, Beaver Creek and Red Creek watersheds which require bacteria TMDLs; therefore, nonsupport of PBCR use in these watersheds is caused by nonpoint sources of bacteria only. The North Fork of the Red River, SH 34, Carter watershed has one continuous point source discharge which does contribute bacteria, but the available data suggests that the proportion of bacteria from point sources is minor. CAFOs maybe contributing bacteria loading in Deep Red Creek and Beaver Creek watersheds. The various nonpoint sources are considered to be the major source of bacteria loading in each watershed that requires a TMDL for bacteria.

Table 3-13 below provides a summary of the estimated fecal coliform loads in cfu/day for the four major nonpoint source categories (commercially raised farm animals, pets, deer, and septic tanks) that contribute to the elevated bacteria concentrations in each watershed. Livestock are estimated to be the largest contributors of fecal coliform loading to land surfaces. It must be noted that while no data are available to estimate populations and fecal loading of wildlife other than deer, a number of bacteria source tracking studies around the nation demonstrate that wild birds and mammals represent a major source of the fecal bacteria found in streams.

Table 3-13 Summary of Fecal Coliform Load Estimates from Nonpoint Sources to Land Surfaces ($x10^9$ counts/day)

Waterbody ID	Waterbody Name	All Livestock	Pets	Deer	Estimated Loads from Septic Tanks
OK311800000070_00	Deer Creek	12,204	173	748	23
OK311800000040_00	Haystack Creek	34,408	664	2,229	84
OK311600010040_00	Sandy Creek (Lebos)	1,064	511	2,641	70
OK311600010020_00	Gypsum Creek	457	607	1,463	42
OK311510020120_00	Sweetwater Creek	57,241	415	1,695	131
OK311510010010_10	North Fork of the Red River, SH 34, Carter	182,852	2,761	3,993	264
OK311500030010_00	Elk Creek, SH 19, Roosevelt	14,273	619	521	39
OK311500010080_00	Otter Creek	64,539	2,209	2,356	180
OK311500010050_00	Stinking Creek	530	14,327	1,732	191
OK311500010020_10	North Fork of the Red River, US 62, Headrick	40,202	2,059	2,844	262
OK311310030050_00	Brush Creek	6,498	176	270	19
OK311310030040_00	Little Deep Red Creek	33,372	2,391	1,343	65
OK311310030010_00	Deep Red Creek	89,157	2,313	3,824	227
OK311310020010_00	West Cache Creek, SH5B, Taylor	16,603	294	827	57
OK311310010070_00	Suttle Creek	14,998	2,603	604	41
OK311300010020_10	East Cache Creek, SH 53, Walters	48,110	2,089	505	33
OK311300010020_00	Cache Creek, East	29,327	235	308	15
OK311200000080_00	Dry Creek	17,551	1,057	784	159
OK311200000060_00	Cow Creek	28,447	2,757	1,085	137
OK311200000030_00	Beaver Creek	32,159	2,471	873	63
OK311100040080_00	Mud Creek, Lower West	37,115	210	1,008	68
OK311100040010_00	Mud Creek	147,767	4,751	6,364	722
OK311100010300_00	Fleetwood Creek	4,963	118	133	8
OK311100010290_00	Red Creek	18,957	131	515	30

The magnitude of loading to a stream may not reflect the magnitude of loading to land surfaces. While no studies have quantified these effects, bacteria may die off or survive at different rates depending on the manure characteristics and a number of other environmental conditions. Also, the structural properties of some manure, such as cow patties, may limit their washoff into streams by runoff. In contrast, malfunctioning septic tank effluent may be present in standing water on the surface, or in shallow groundwater, which may enhance its conveyance to streams.

Of the 24 watersheds in the Study Area that require turbidity TMDLs, only two of them, Otter Creek (OK311500010080_00) and Mud Creek (OK311100040010_00), have industrial permitted sources of TSS that will necessitate a WLA. Sixteen of the watersheds have other permitted activities such as construction and/or mining that contribute some TSS loading. Therefore, nonsupport of WWAC use in the all but two watersheds is caused primarily by nonpoint sources of TSS. Sediment loading of streams can originate from natural erosion processes, including the weathering of soil, rocks, and uncultivated land; geological abrasion; and other natural phenomena. There is insufficient data available to quantify contributions of TSS from these natural processes. TSS or sediment loading can also occur under non-runoff conditions as a result of anthropogenic activities in riparian corridors which cause erosive conditions. Given the lack of data to establish the background conditions for TSS/turbidity, separating background loading from nonpoint sources whether it is from natural or anthropogenic processes is not feasible in this TMDL development.

SECTION 4
TECHNICAL APPROACH AND METHODS

The objective of a TMDL is to estimate allowable pollutant loads and to allocate these loads to the known pollutant sources in the watershed so appropriate control measures can be implemented and the WQS achieved. A TMDL is expressed as the sum of three elements as described in the following mathematical equation:

$$\mathbf{TMDL = \Sigma\ WLA + \Sigma\ LA + MOS}$$

The WLA is the portion of the TMDL allocated to existing and future point sources. The LA is the portion of the TMDL allocated to nonpoint sources, including natural background sources. The MOS is intended to ensure that WQSs will be met. Thus, the allowable pollutant load that can be allocated to point and nonpoint sources can then be defined as the TMDL minus the MOS.

40 CFR, §130.2(1), states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For fecal coliform, *E. coli*, or Enterococci bacteria, TMDLs are expressed as colony-forming units per day, where possible, or as a percent reduction goal (PRG), and represent the maximum one-day load the stream can assimilate while still attaining the WQS. Turbidity TMDLs will be derived from TSS calculations and expressed in pounds (lbs) per day which will represent the maximum one-day load the stream can assimilate while still attaining the WQS, as well as a PRG.

4.1 Determining a Surrogate Target for Turbidity

Turbidity is a commonly measured indicator of the suspended solids load in streams. However, turbidity is an optical property of water, which measures scattering of light by suspended solids and colloidal matter. To develop TMDLs, a gravimetric (mass-based) measure of solids loading is required to express loads. There is often a strong relationship between the total suspended solids concentration and turbidity. Therefore, the TSS load, which is expressed as mass per time, is used as a surrogate for turbidity.

To determine the relationship between turbidity and TSS, a linear regression between TSS and turbidity was developed using data collected from 1998 to 2008 at stations within the Study Area. Prior to developing the regression the following steps were taken to refine the dataset:

- Replace TSS samples of "<10" with 9.99;
- Remove data collected under high flow conditions exceeding the base-flow criterion. This means that measurements corresponding to flow exceedance percentiles lower than 25th were not used in the regression;
- Check rainfall data on the day when samples were collected and on the previous two days. If there was a significant rainfall event (>= 1.0 inch) in any of these days, the sample will be excluded from regression analysis with one exception. If the significant rainfall happened on the sampling day and the turbidity reading was less than 25 NTUs (half of turbidity standard for streams), the sample will not be excluded from analysis because most likely the rainfall occurred after the sample was taken, and
- Log-transform both turbidity and TSS data to minimize effects of their non-linear data distributions.

When ordinary least squares regression (OLS) is applied to ascertain the best relationship between two variables (i.e., X and Y), one variable (Y) is considered "dependent" on the other variable (X), but X must be considered "independent" of the other, and known without measurement error. OLS minimizes the differences, or residuals, between measured Y values and Y values predicted based on the X variable.

For current purposes, a relationship is necessary to predict TSS concentrations from measured turbidity values, but also to translate the TSS-based TMDL back to instream turbidity values. For this purpose, an alternate regression fitting procedure known as the line of organic correlation (LOC) was applied. The LOC has three advantages over OLS (Helsel and Hirsch 2002):

- LOC minimizes fitted residuals in both the X and Y directions;
- It provides a unique best-fit line regardless of which parameter is used as the independent variable; and
- Regression-fitted values have the same variance as the original data.

The LOC minimizes the areas of the right triangles formed by horizontal and vertical lines drawn from observations to the fitted line. The slope of the LOC line equals the geometric mean of the Y on X (TSS on turbidity) and X on Y (turbidity on TSS) OLS slopes, and is calculated as:

$$m1 = \sqrt{m \cdot m'} = sign[r] \cdot \frac{s_y}{s_x}$$

where $m1$ is the slope of the LOC line, m is the TSS on turbidity OLS slope, m' is the turbidity on TSS OLS slope, r is the TSS-turbidity correlation coefficient, s_y is the standard deviation of the TSS measurements, and s_x is the standard deviation of the turbidity measurements.

The intercept of the LOC ($b1$) is subsequently found by fitting the line with the LOC slope through the point (mean turbidity, mean TSS). The correlation between TSS and turbidity, along with the LOC and the OLS lines are shown in Figures 4-1 through Figure 4-24

Figure 4-1 Linear Regression for TSS-Turbidity for Deer Creek (OK311800000070_00)

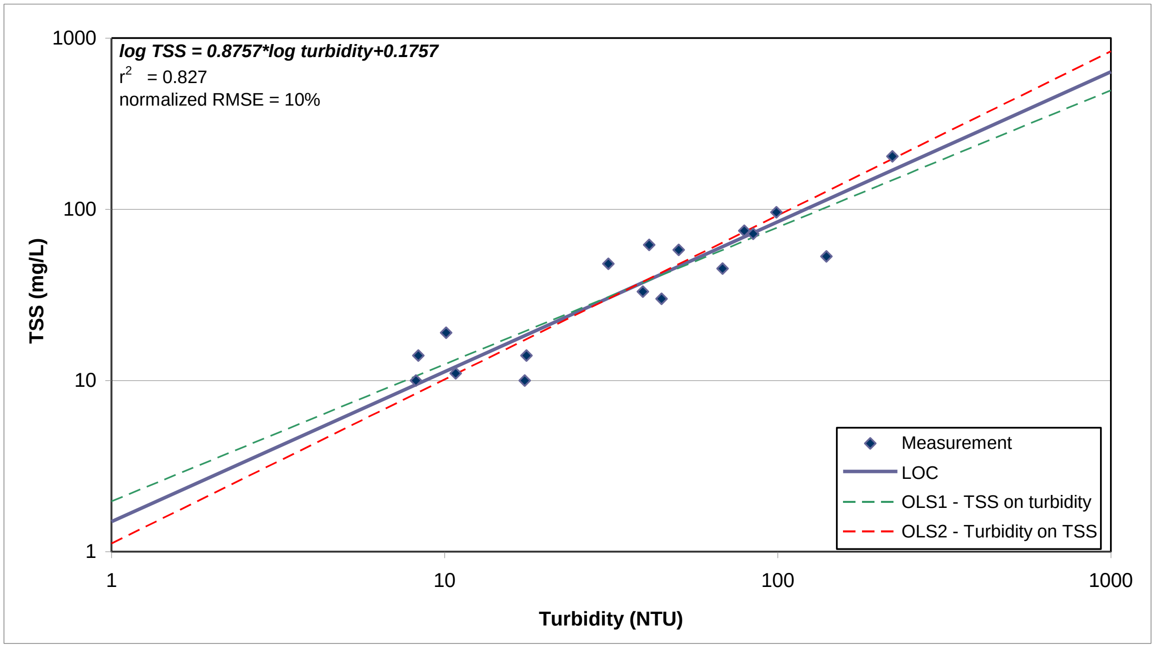


Figure 4-2 Linear Regression for TSS-Turbidity for Haystack Creek (OK311800000040_00)

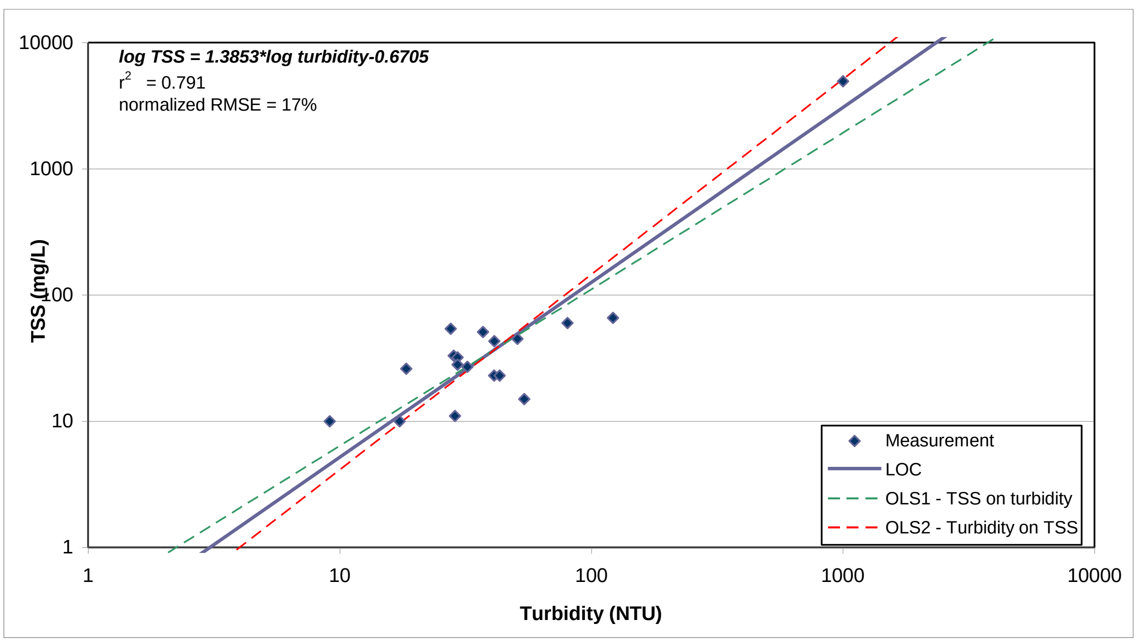


Figure 4-3 Linear Regression for TSS-Turbidity for Sandy Creek (Lebos) (OK311600010040_00)

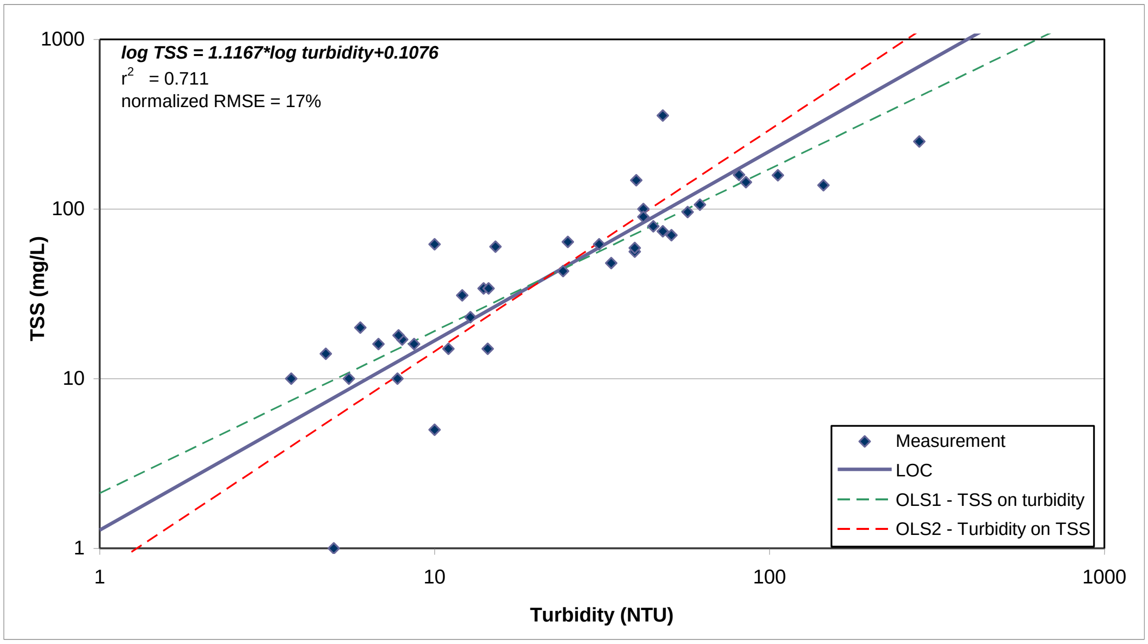


Figure 4-4 Linear Regression for TSS-Turbidity for Gypsum Creek (OK311600010020_00)

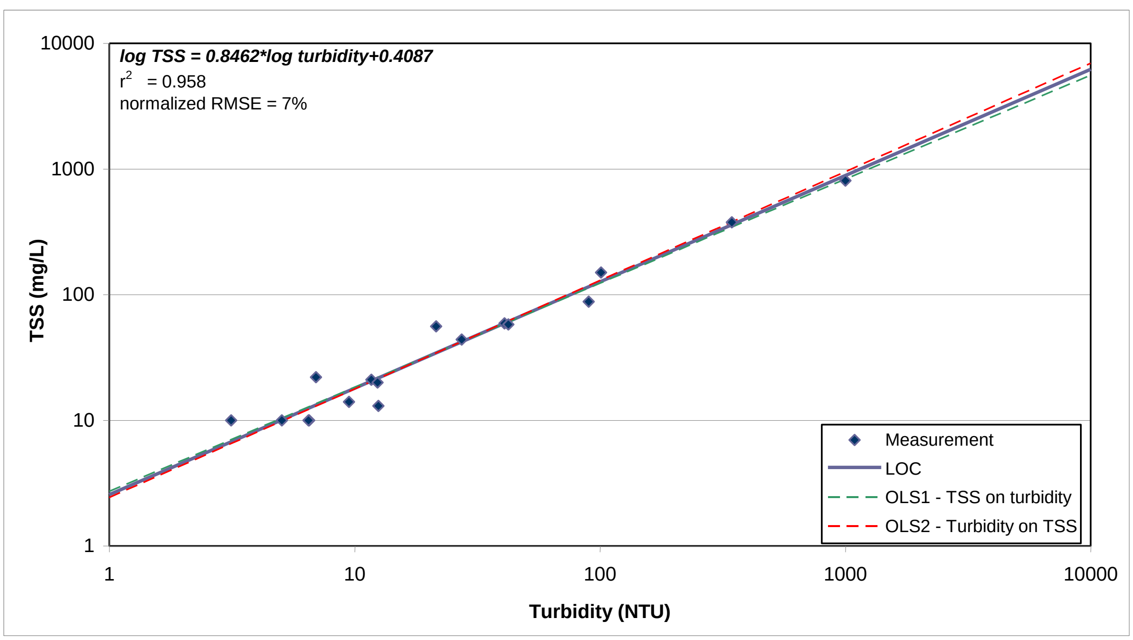


Figure 4-5 Linear Regression for TSS-Turbidity for Sweetwater Creek (OK311510020120_00)

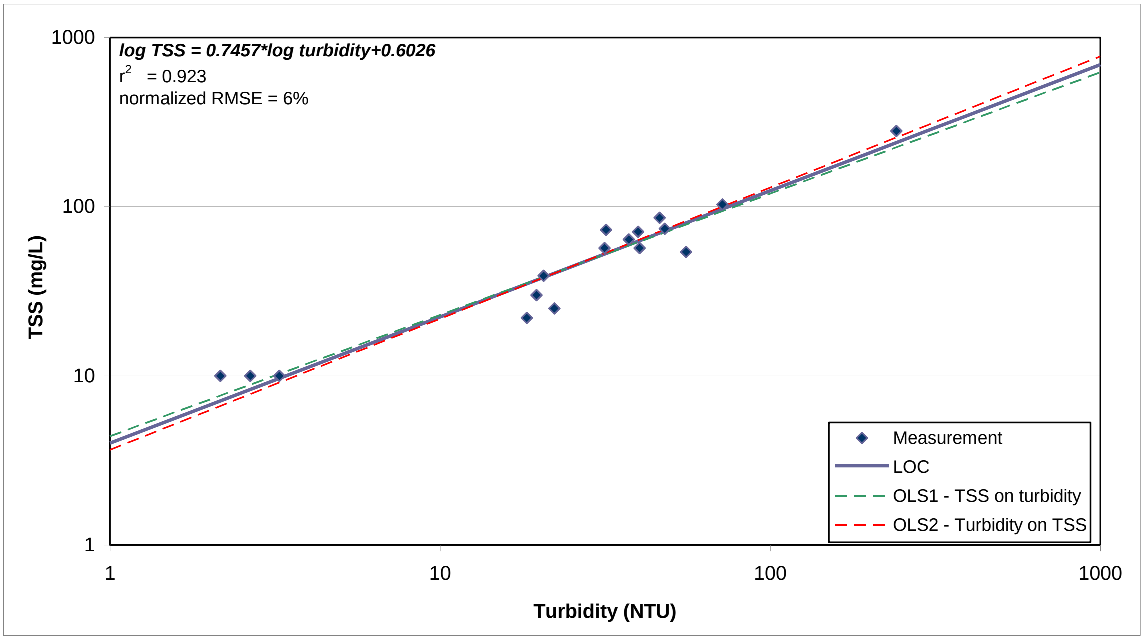


Figure 4-6 Linear Regression for TSS-Turbidity for the Red River, North Fork, Carter (OK311510010010_10)

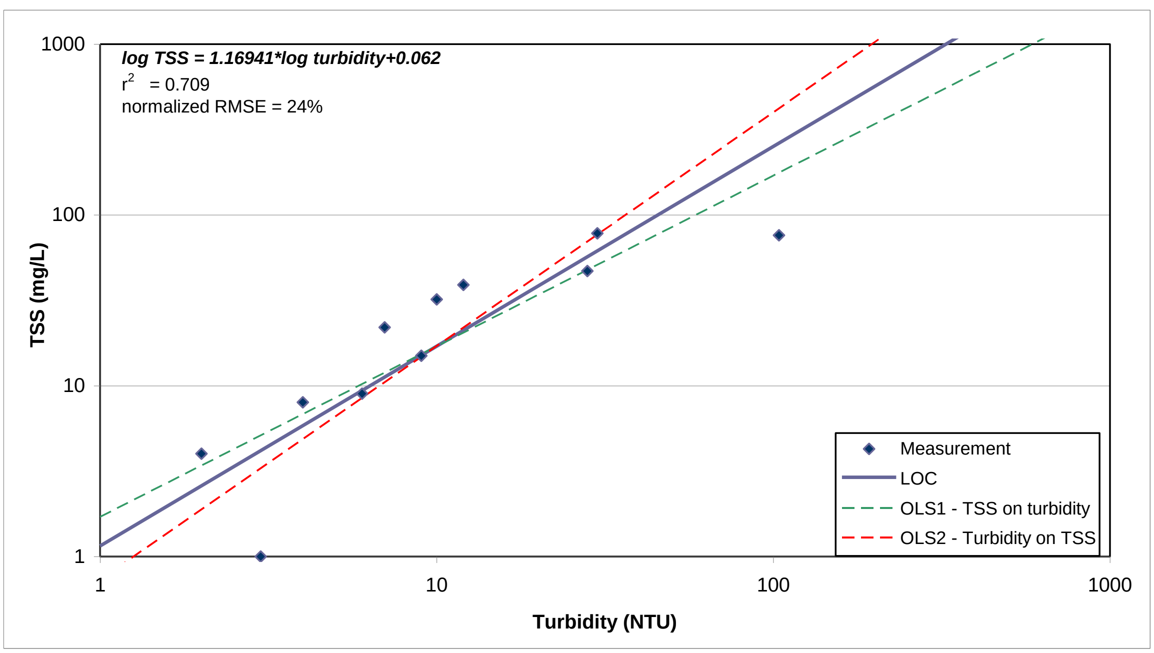


Figure 4-7 Linear Regression for TSS-Turbidity for Elk Creek (OK311500030010_00)

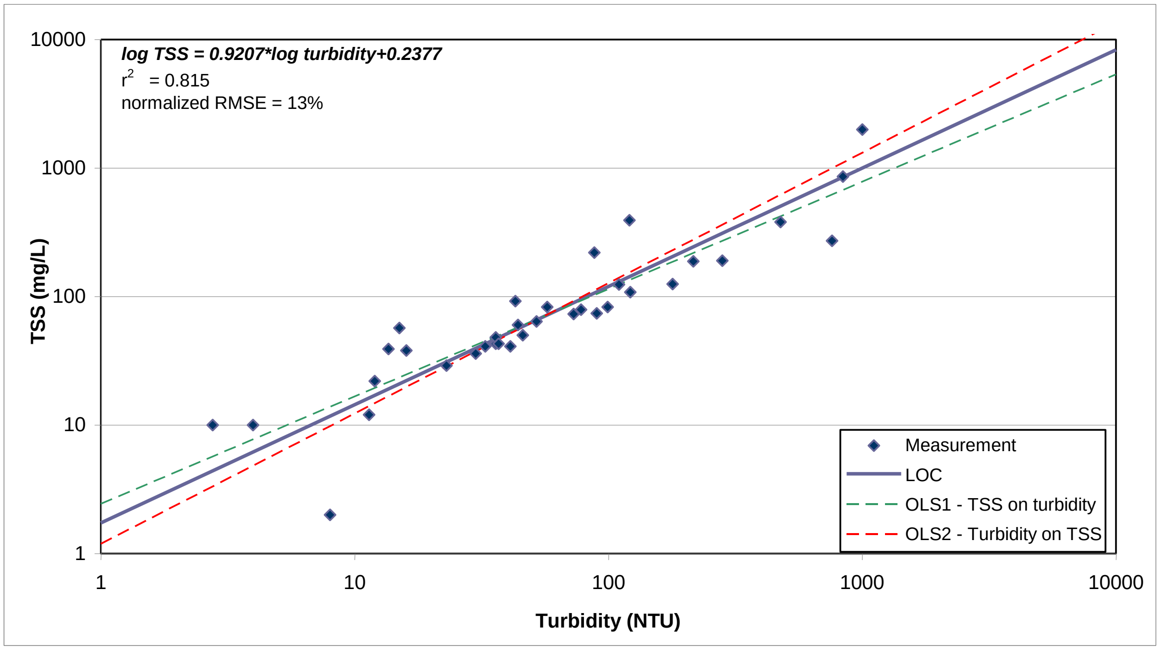


Figure 4-8 Linear Regression for TSS-Turbidity for Otter Creek (OK311500010080_00)

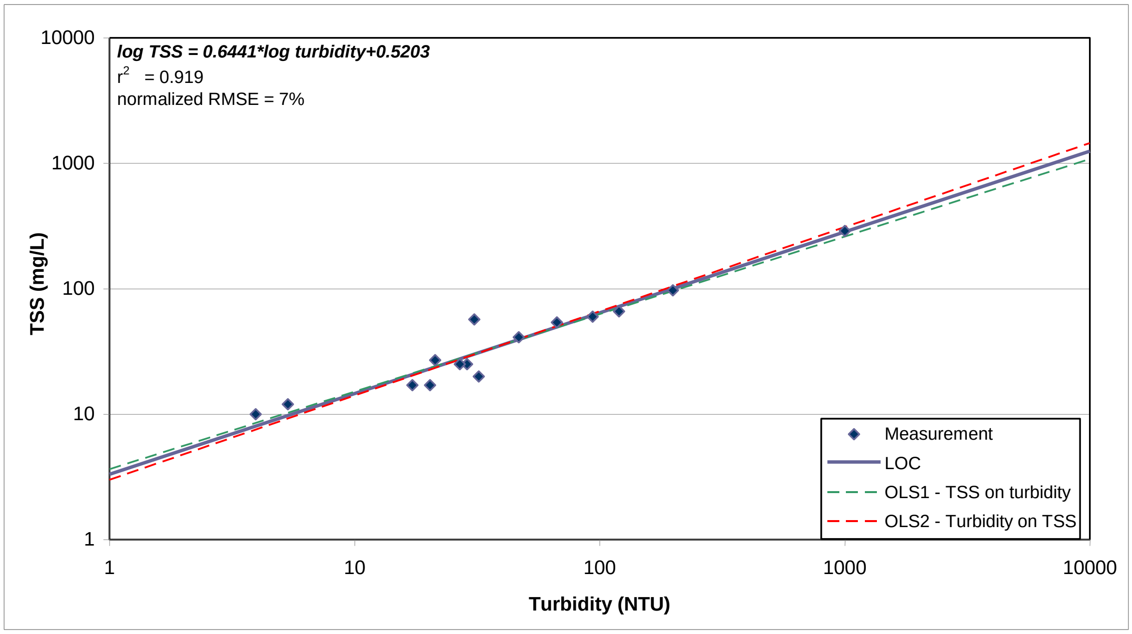


Figure 4-9 Linear Regression for TSS-Turbidity for Stinking Creek (OK311500010050_00)

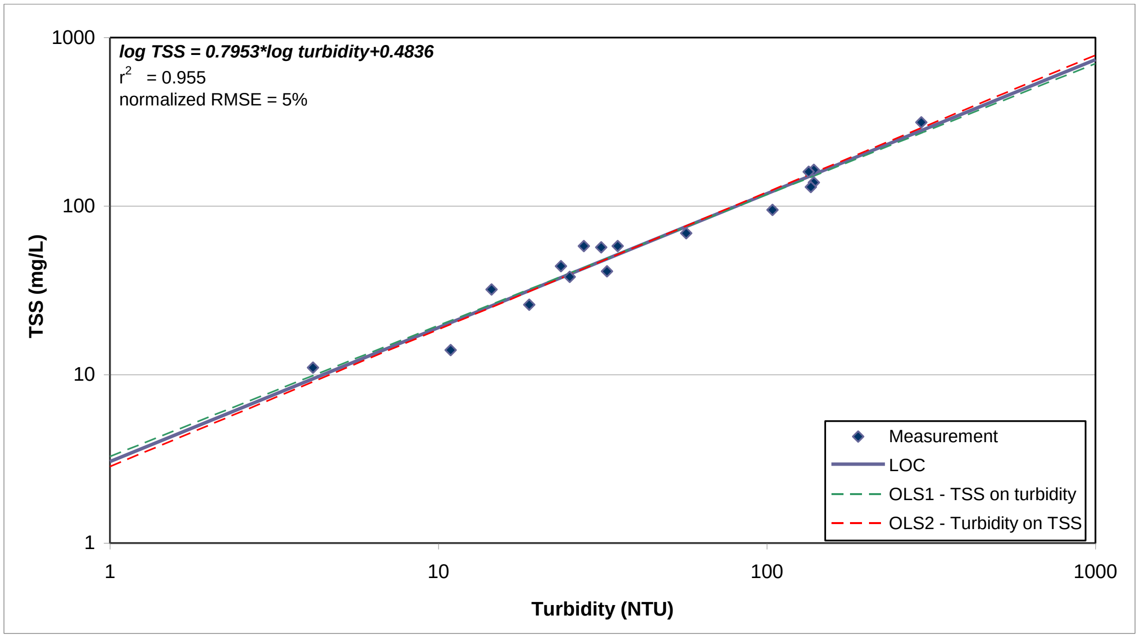


Figure 4-10 Linear Regression for TSS-Turbidity for the Red River, North Fork, Headrick (OK311500010020_10)

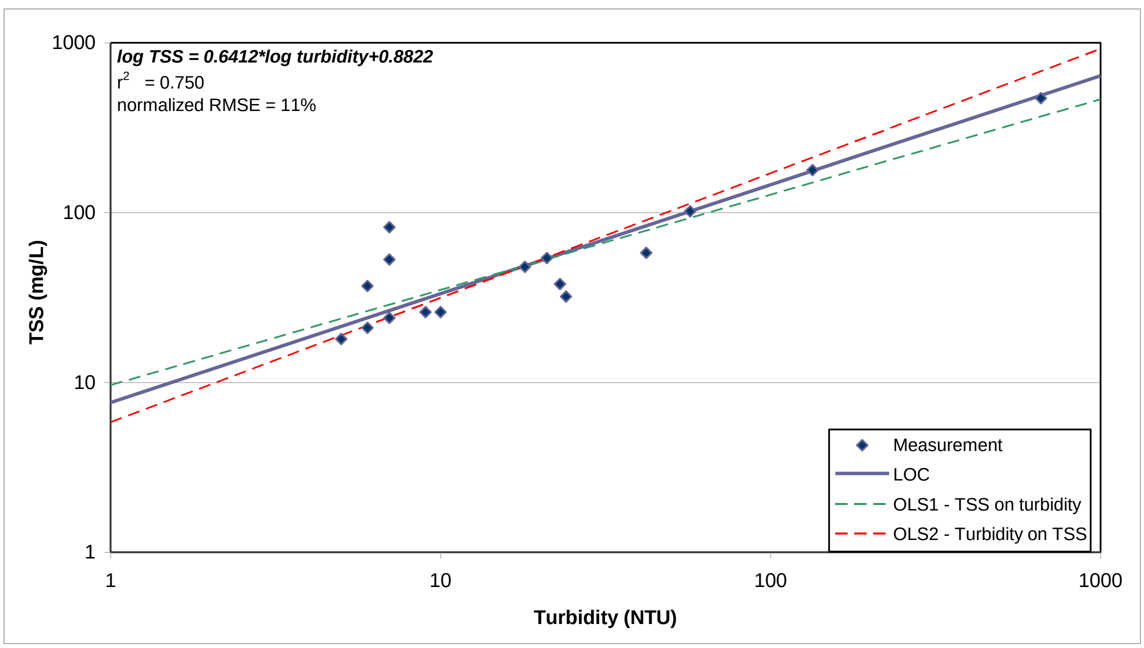


Figure 4-11 Linear Regression for TSS-Turbidity for Brush Creek (OK311310030050_00)

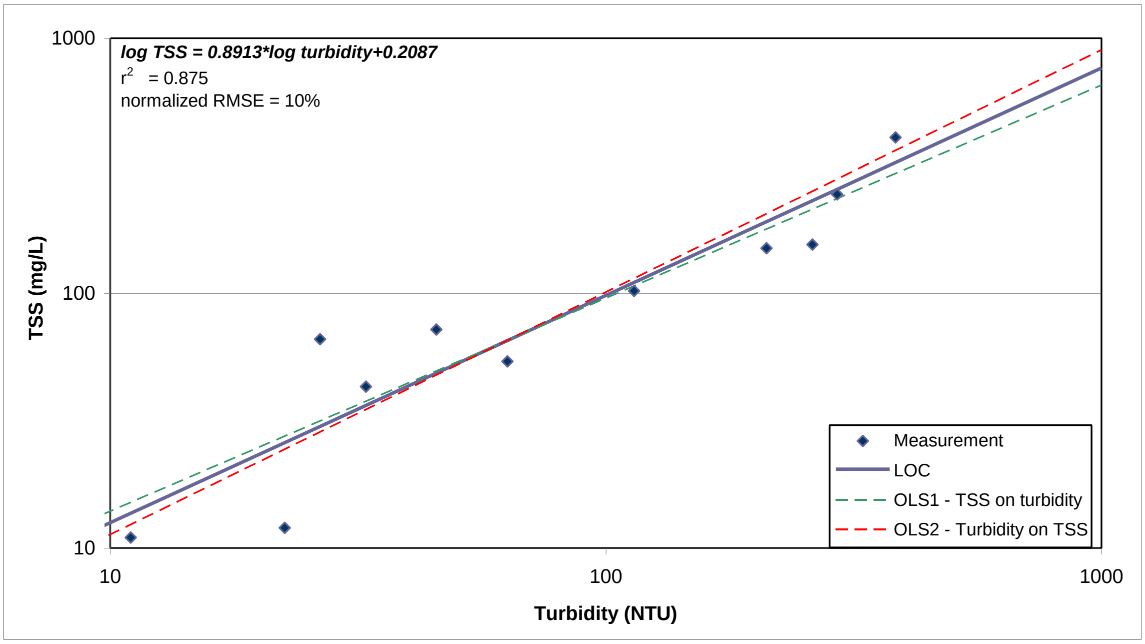


Figure 4-12 Linear Regression for TSS-Turbidity for Little Deep Red Creek (OK311310030040_00)

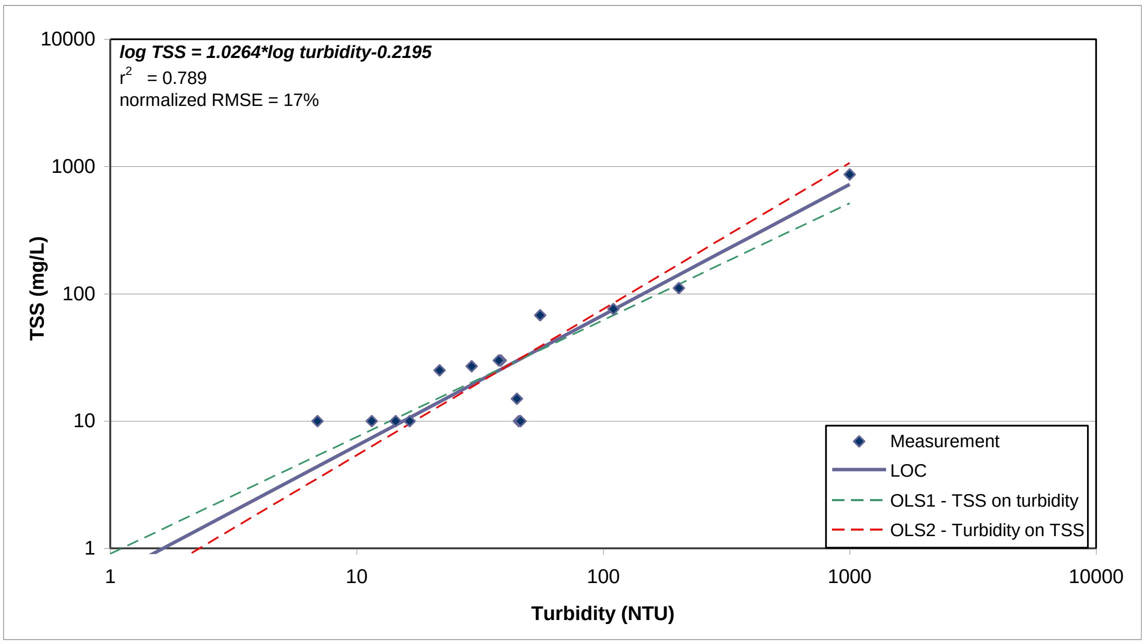


Figure 4-13 Linear Regression for TSS-Turbidity for Deep Red Creek (OK311310030010_00)

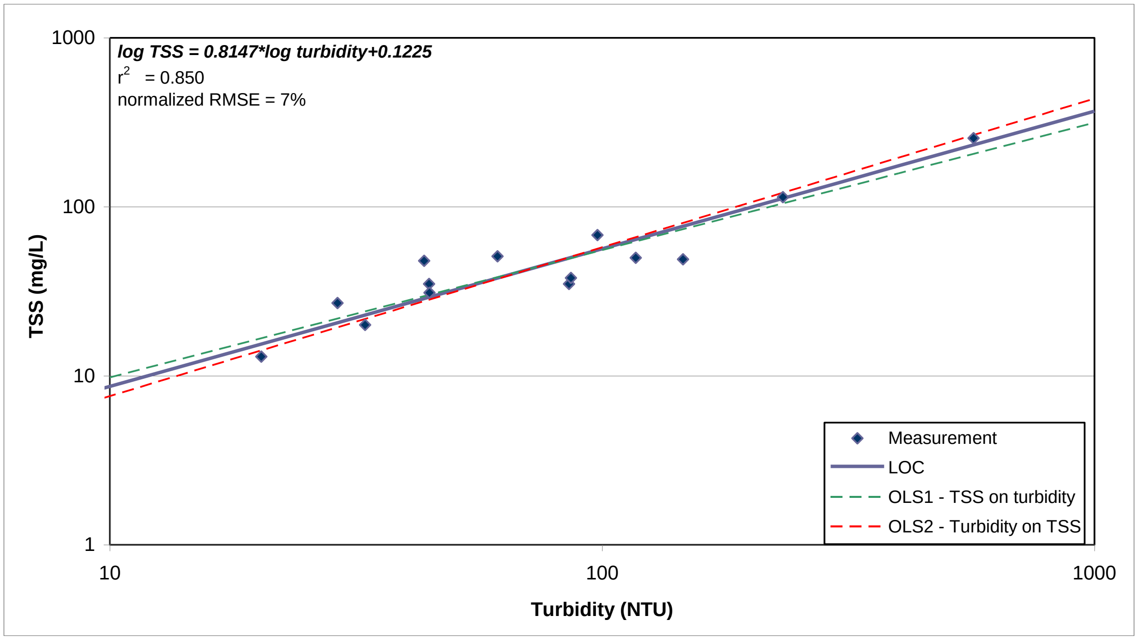


Figure 4-14 Linear Regression for TSS-Turbidity for West Cache Creek (OK311310020010_00)

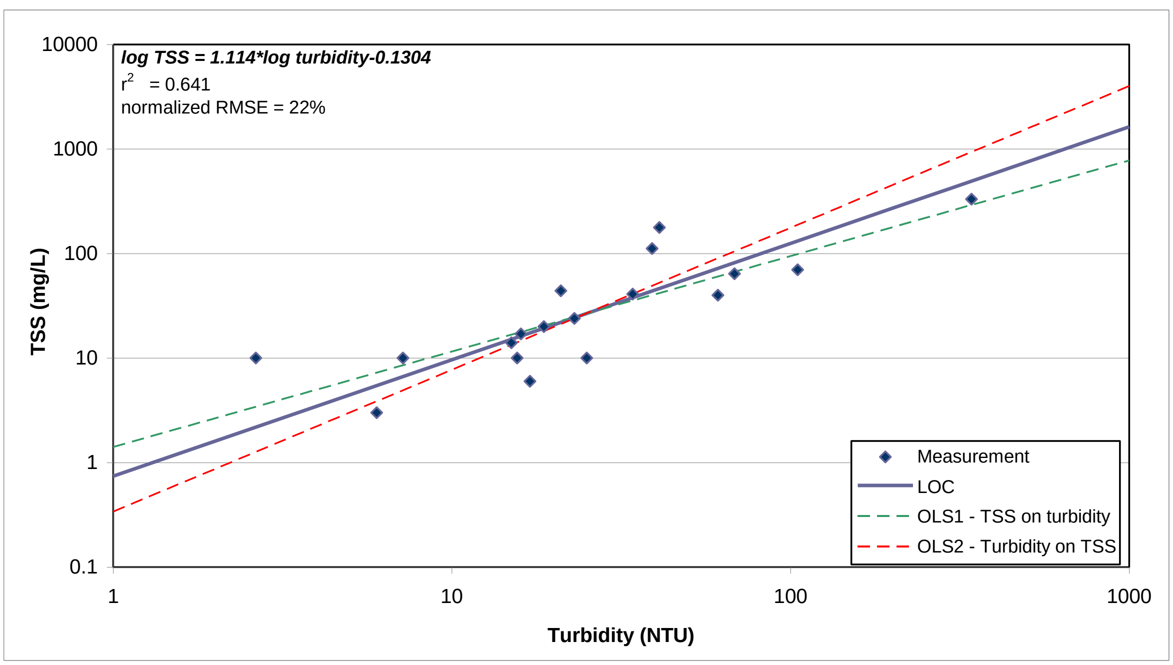


Figure 4-15 Linear Regression for TSS-Turbidity for Suttle Creek (OK311310010070_00)

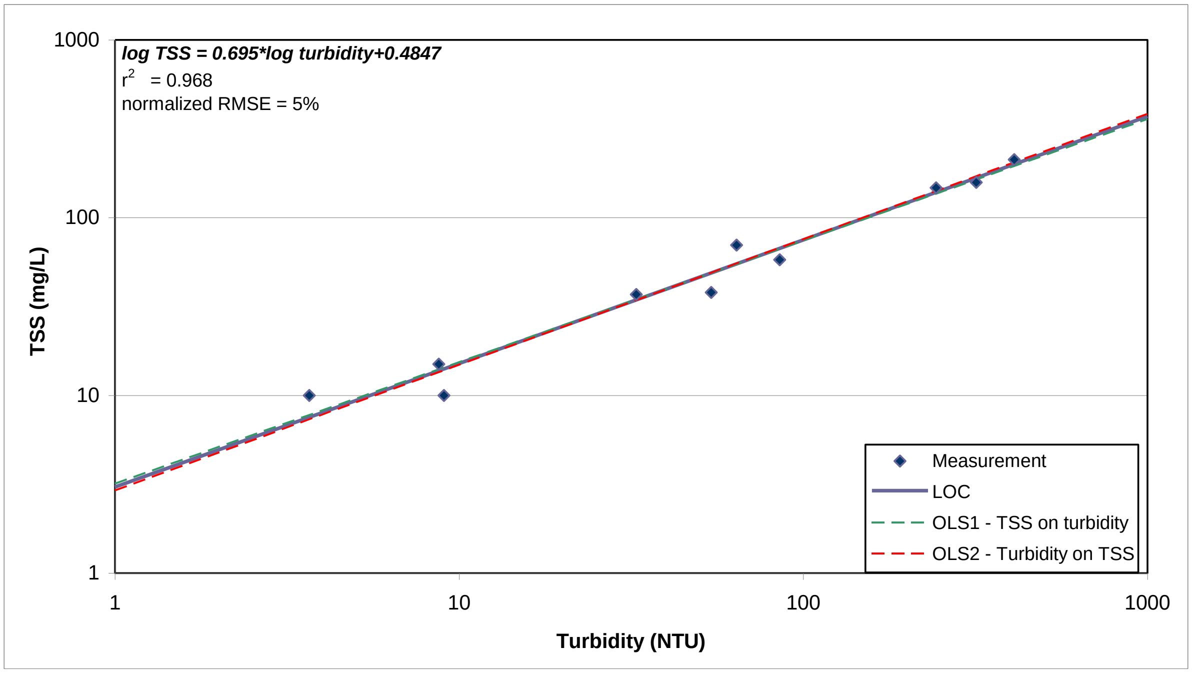


Figure 4-16 Linear Regression for TSS-Turbidity for East Cache Creek, Walters (OK311300010020_10)

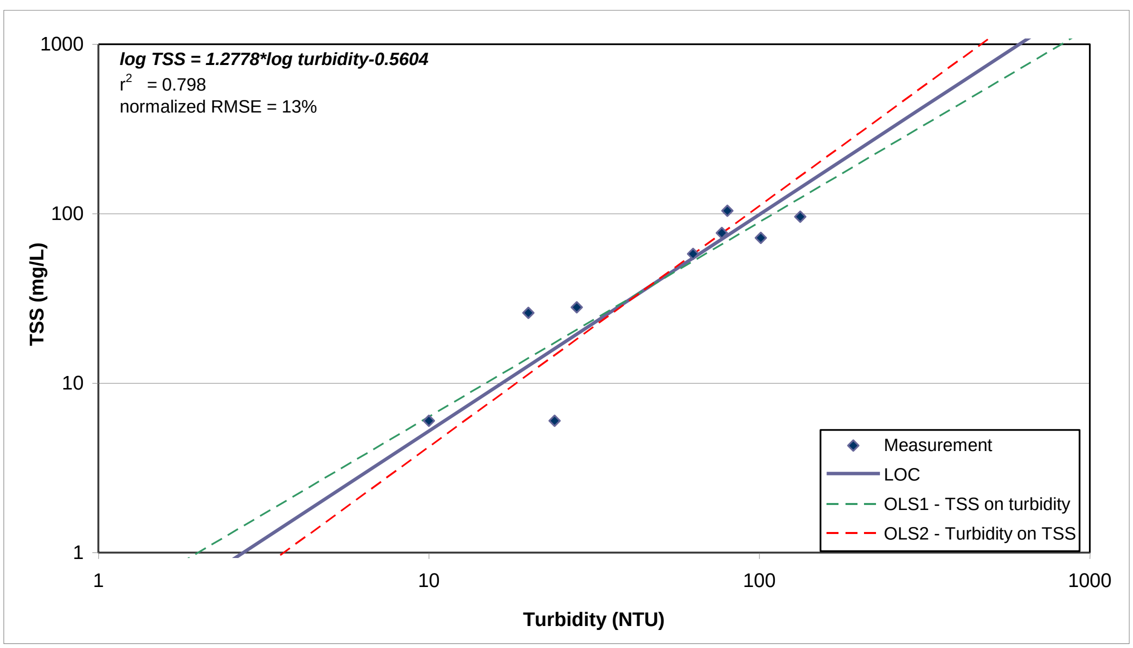


Figure 4-17 Linear Regression for TSS-Turbidity for East Cache Creek (OK311300010020_00)

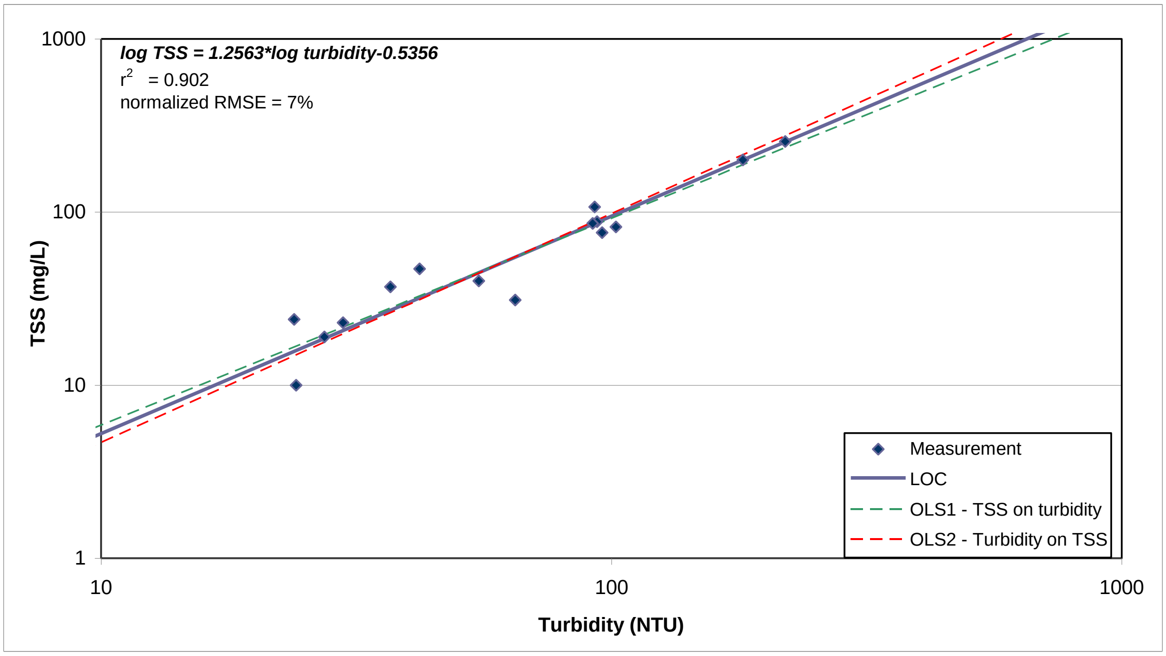


Figure 4-18 Linear Regression for TSS-Turbidity for Dry Creek (OK311200000080_00)

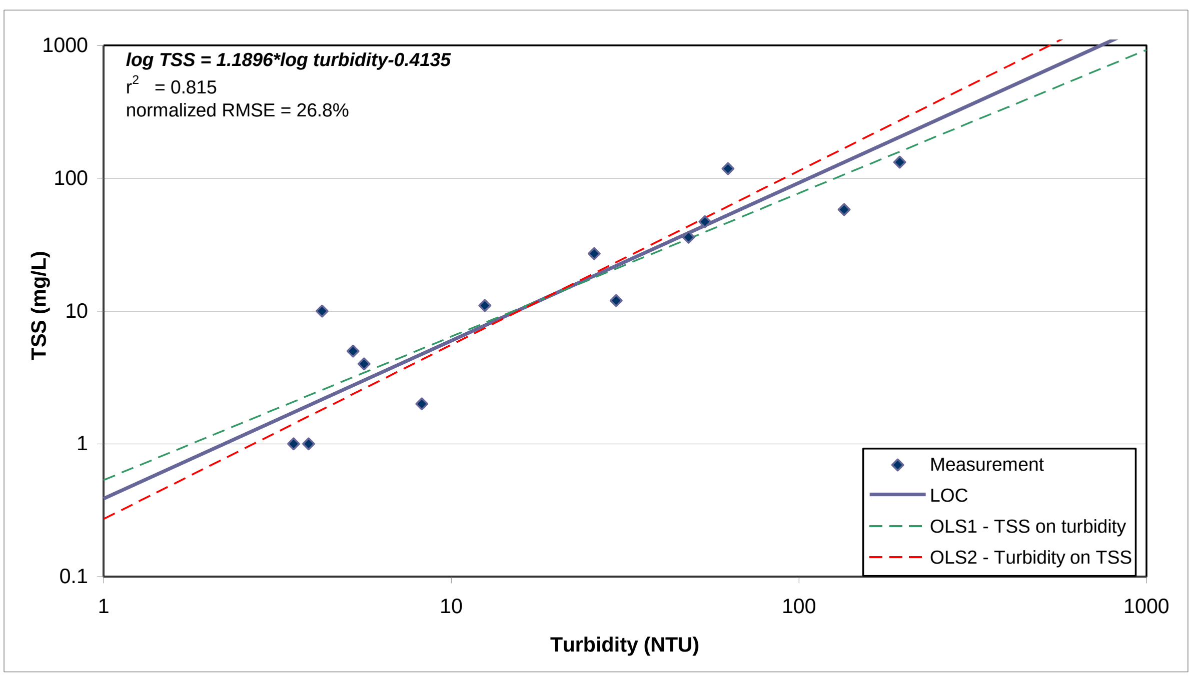


Figure 4-19 Linear Regression for TSS-Turbidity for Cow Creek (OK311200000060_00)

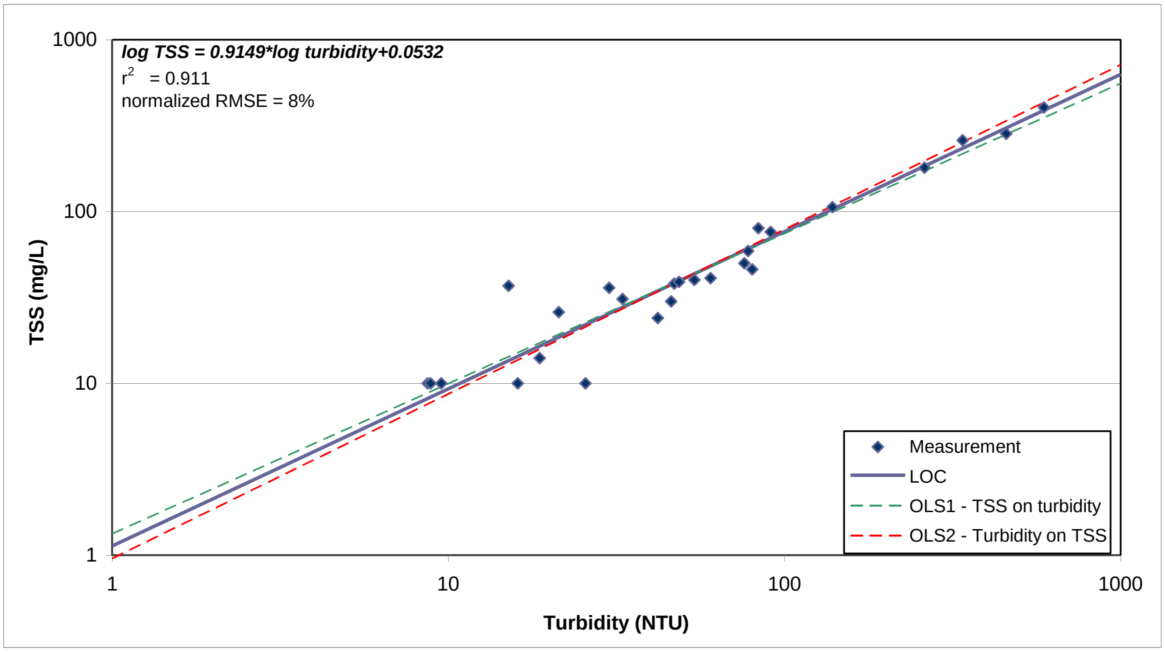


Figure 4-20 Linear Regression for TSS-Turbidity for Beaver Creek (OK311200000030_00)

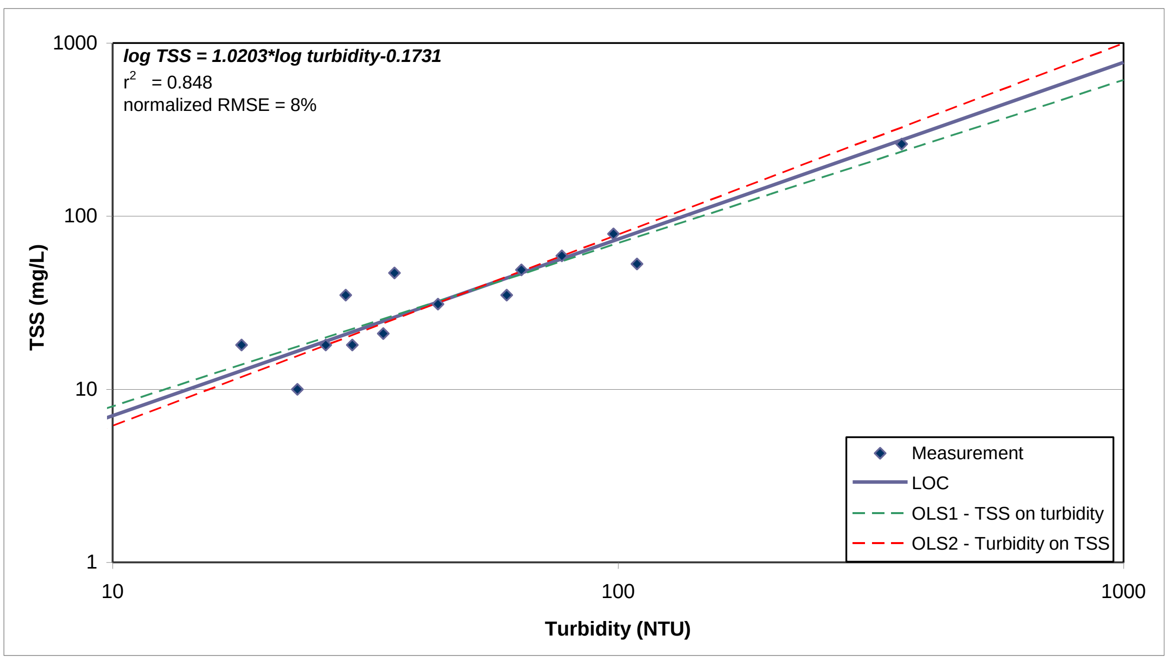


Figure 4-21 Linear Regression for TSS-Turbidity for Mud Creek, Lower West (OK311100040080_00)

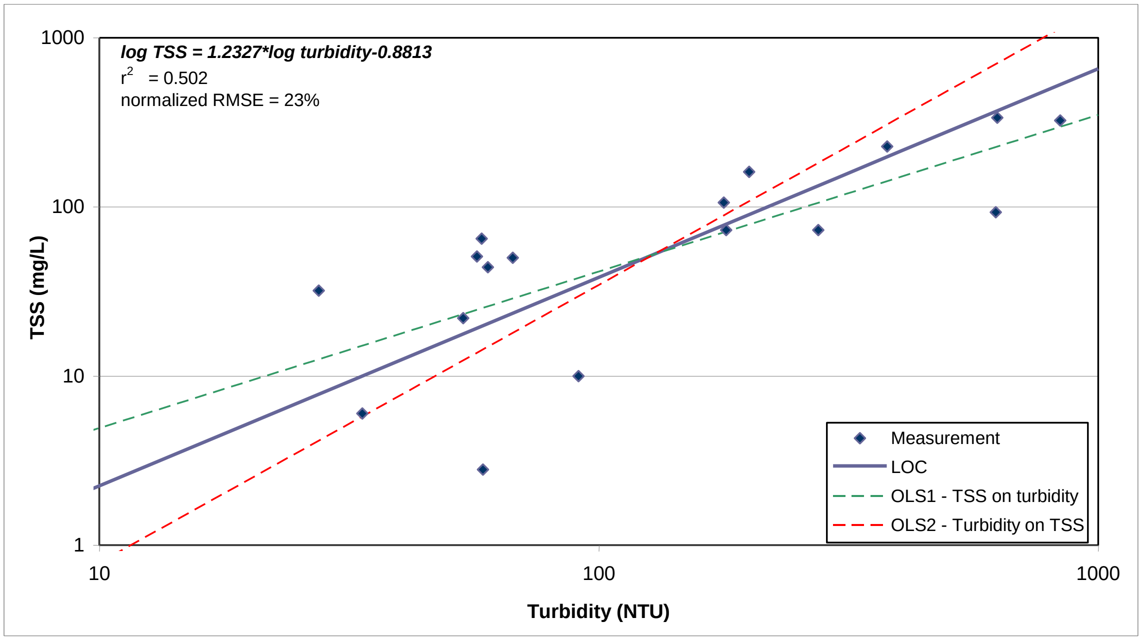


Figure 4-22 Linear Regression for TSS-Turbidity for Mud Creek (OK311100040010_00)

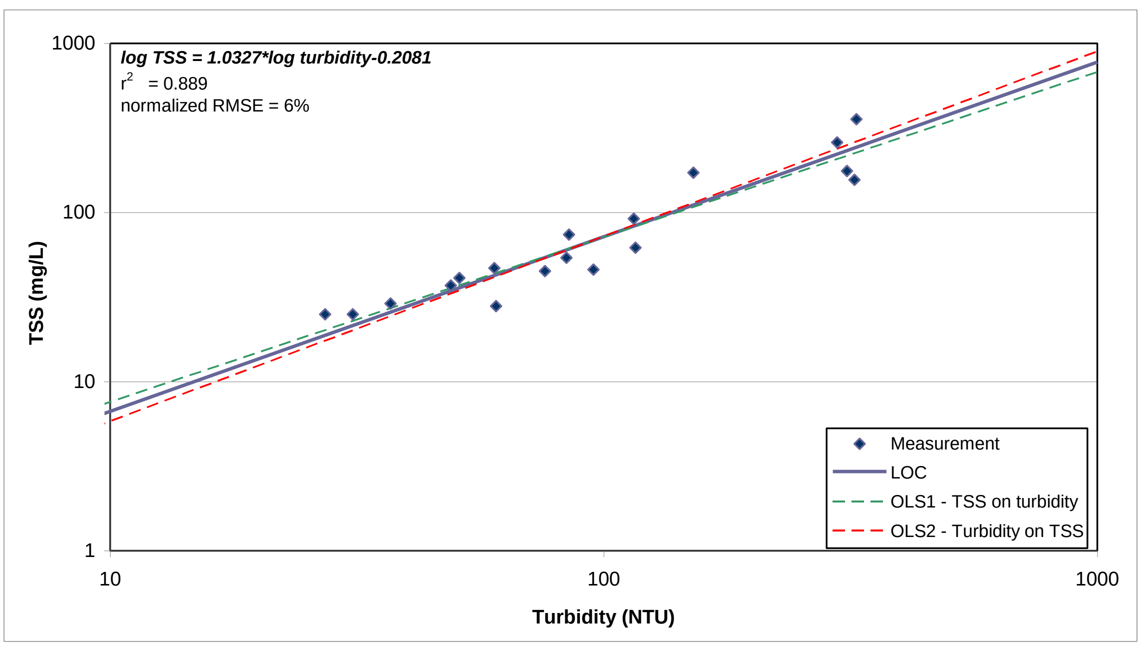


Figure 4-23 Linear Regression for TSS-Turbidity for Fleetwood Creek (OK311100010300_00)

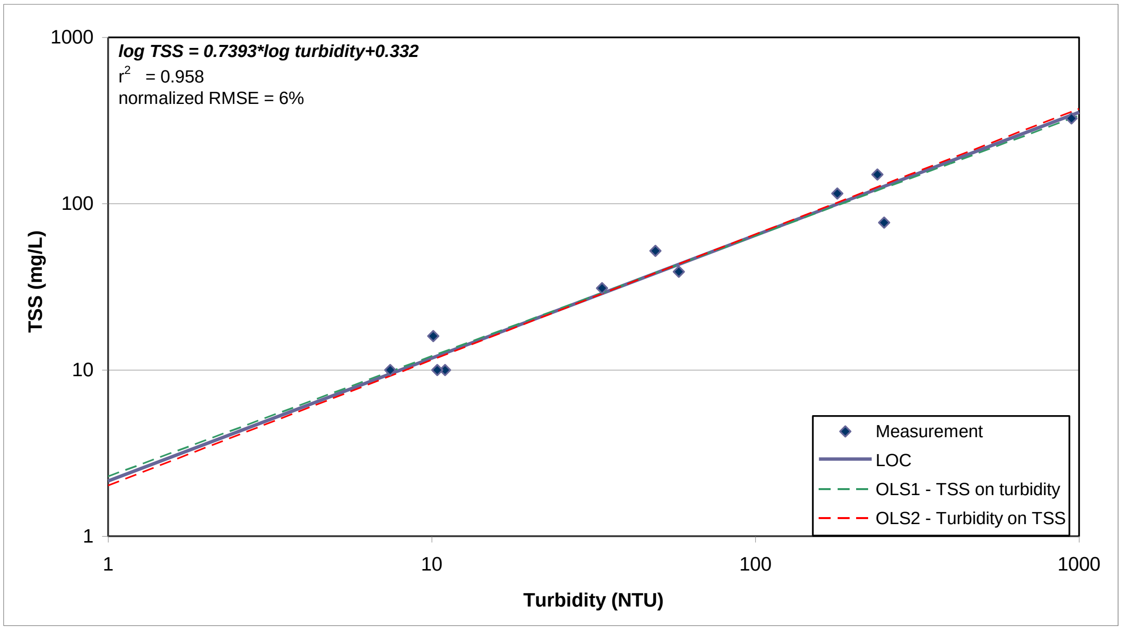
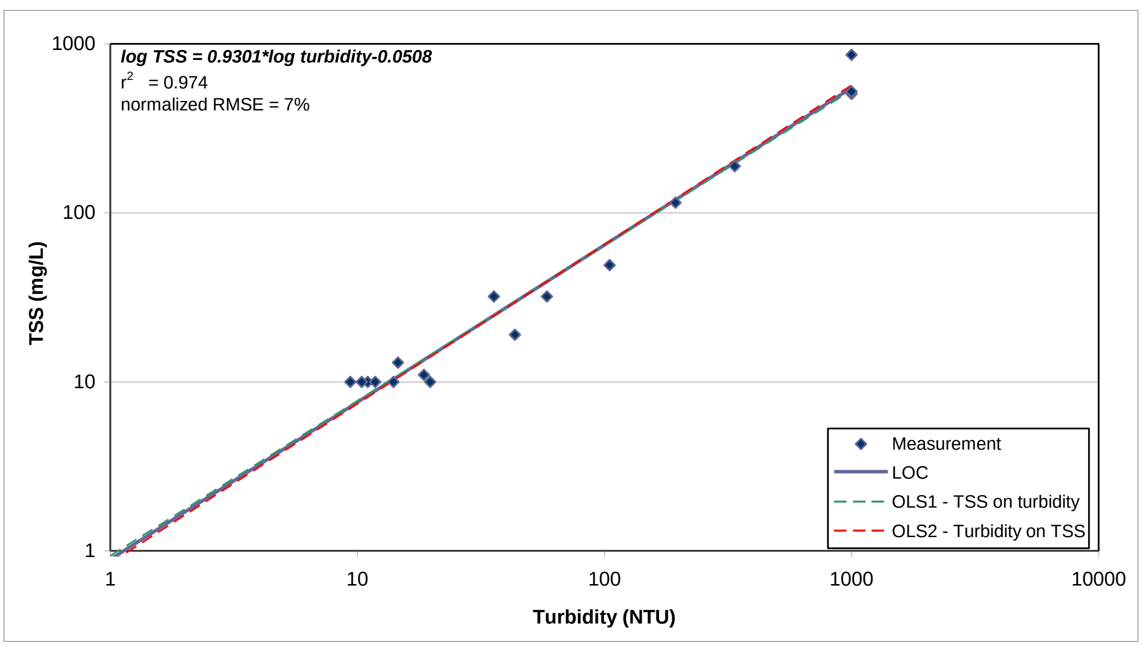


Figure 4-24 Linear Regression for TSS-Turbidity for Red Creek (OK311100010290_00)



The NRMSE and R-square (r^2) were used as the primary measures of goodness-of-fit. For example, as shown in Figure 4-24, the LOC yields a NRMSE value of 7 which means the root mean square error (RMSE) is 7% of the average of the measured TSS values. The R-square (r^2) value indicates the fraction of the total variance in TSS or turbidity observations that is explained by the LOC. Table 4-1 shows the statistics of the regressions and the resultant TSS goals.

Table 4-1 Regression Statistics and TSS Goals

Waterbody ID	Waterbody Name	R-square	NRMSE	TSS Goal (mg/L)[a]	MOS[b]
OK311800000070_00	Deer Creek	0.827	10.1%	46	15%
OK311800000040_00	Haystack Creek	0.791	16.7%	48	20%
OK311600010040_00	Sandy Creek (Lebos)	0.711	16.9%	101	20%
OK311600010020_00	Gypsum Creek	0.958	7.3%	70	10%
OK311510020120_00	Sweetwater Creek	0.923	6.5%	74	10%
OK311510010010_10	North Fork of the Red River, SH 34, Carter	0.709	24.3%	112	25%
OK311500030010_00	Elk Creek, SH 19, Roosevelt	0.815	13.0%	63	15%
OK311500010080_00	Otter Creek	0.92	6.8%	41	10%
OK311500010050_00	Stinking Creek	0.955	4.5%	68	10%
OK311500010020_10	North Fork of the Red River, US 62, Headrick	0.75	10.6%	94	15%
OK311310030050_00	Brush Creek	0.875	9.5%	53	10%
OK311310030040_00	Little Deep Red Creek	0.789	16.8%	34	20%
OK311310030010_00	Deep Red Creek	0.85	7.1%	32	10%
OK311310020010_00	Cache Creek, West	0.641	21.7%	59	25%
OK311310010070_00	Suttle Creek	0.968	5.0%	46	10%
OK311300010020_10	Cache Creek, East, Walters	0.798	13.3%	41	15%
OK311300010020_00	Cache Creek, East	0.902	6.8%	40	10%
OK311200000080_00	Dry Creek	0.815	26.8%	41	25%
OK311200000060_00	Cow Creek	0.911	8.4%	41	10%
OK311200000030_00	Beaver Creek	0.848	8.5%	36	10%
OK311100040080_00	Mud Creek, Lower West	0.502	23.0%	16	25%
OK311100040010_00	Mud Creek	0.889	6.4%	33	10%
OK311100010300_00	Fleetwood Creek	0.958	6.4%	39	10%
OK311100010290_00	Red Creek	0.974	6.8%	34	10%

[a] Calculated using the regression equation and the turbidity standard (50 NTU)
[b] Based on the goodness-of-fit of the turbidity-TSS regression (NRMSE)
[c] WQ goal minus MOS

It was noted that there were a few outliers that exerted undue influence on the regression relationship. These outliers were identified by applying the Tukey's Boxplot method (Tukey 1977) to the dataset of the distances from observed points to the regression line. The Tukey Method is based on the interquartile range (IQR), the difference between the 75^{th} percentile (Q_3) and 25^{th} percentile (Q_1) of distances between observed points and the LOC. Using the Tukey method, any point with an error greater than Q_3 + 1.5* IQR or less than Q_1 – 1.5*IQR was identified as an outlier and removed from the regression dataset. The above regressions were calculated using the dataset with outliers removed.

The Tukey Method is equivalent to using three times the standard deviation to identify outliers if the residuals (observed - predicted) follow a normal distribution. The probability of sampling results being within three standard deviations of the mean is 99.73% while the probability for the Tukey Method is 99.65%. If three times the standard deviation is used to identify outliers, it is necessary to first confirm that the residuals are indeed normally distributed. This is difficult to do because of the size limitations of the existing turbidity & TSS dataset. Tukey's method does not rely on any assumption about the distribution of the residuals. It can be used regardless of the shape of distribution.

Outliers were removed from the dataset only for calculating the turbidity-TSS relationship, not from the dataset used to develop the TMDL.

4.2 Using Load Duration Curves to Develop TMDLs

The TMDL calculations presented in this report are derived from load duration curves (LDC). LDCs facilitate rapid development of TMDLs, and as a TMDL development tool are effective at identifying whether impairments are associated with point or nonpoint sources. The technical approach for using LDCs for TMDL development includes the following steps that are described in Subsections 4.3 through 4.5 below:

Preparing flow duration curves for gaged and ungaged WQM stations;

- Estimating existing loading in the waterbody using ambient bacteria water quality data; and estimating loading in the waterbody using measured TSS water quality data and turbidity-converted data; and

Using LDCs to identify the critical condition that will dictate loading reductions and the overall percent reduction goal (PRG) necessary to attain WQS.

Historically, in developing WLAs for pollutants from point sources, it was customary to designate a critical low flow condition (*e.g.*, 7Q2) at which the maximum permissible loading was calculated. As water quality management efforts expanded in scope to quantitatively address nonpoint sources of pollution and types of pollutants, it became clear that this single critical low flow condition was inadequate to ensure adequate water quality across a range of flow conditions. Use of the LDC obviates the need to determine a design storm or selected flow recurrence interval with which to characterize the appropriate flow level for the assessment of critical conditions. For waterbodies impacted by both point and nonpoint sources, the "nonpoint source critical condition" would typically occur during high flows, when rainfall runoff would contribute the bulk of the pollutant load, while the "point source critical condition" would typically occur during low flows, when WWTP effluents would dominate the base flow of the impaired water. However, flow range is only a general indicator of the relative proportion of point/nonpoint contributions. It is not used in this report to quantify point source or nonpoint source contributions. Violations that occur during low flows may not be caused exclusively by point sources. Violations have been noted in some watersheds that contain no point sources.

LDCs display the maximum allowable load over the complete range of flow conditions by a line using the calculation of flow multiplied by a water quality criterion. The TMDL can be expressed as a continuous function of flow, equal to the line, or as a discrete value derived from a specific flow condition.

4.3 Development of Flow Duration Curves

Flow duration curves serve as the foundation of LDCs and are graphical representations of the flow characteristics of a stream at a given site. Flow duration curves utilize the historical hydrologic record from stream gages to forecast future recurrence frequencies. Many WQM stations throughout Oklahoma do not have long-term flow data and therefore, flow frequencies must be estimated. Seventeen of the twenty-four waterbodies in the Study Area do not have USGS gage stations. The default approach used to develop flow frequencies necessary to establish flow duration curves considers watershed differences in rainfall, land use, and the hydrologic properties of soil that govern runoff and retention. A detailed explanation of the methods for estimating flow for ungaged streams is provided in Appendix B. The most basic method to estimate flows at an ungaged site involves 1) identifying an upstream or downstream flow gage; 2) calculating the contributing drainage areas of the ungaged sites and the flow gage; and 3) calculating daily flows at the ungaged site by using the flow at the gaged site multiplied by the drainage area ratio.

Flow duration curves are a type of cumulative distribution function. The flow duration curve represents the fraction of flow observations that exceed a given flow at the site of interest. The observed flow values are first ranked from highest to lowest, then, for each observation, the percentage of observations exceeding that flow is calculated. The flow value is read from the ordinate (y-axis), which is typically on a logarithmic scale since the high flows would otherwise overwhelm the low flows. The flow exceedance frequency is read from the abscissa, which is numbered from 0 to 100 percent, and may or may not be logarithmic. The lowest measured flow occurs at an exceedance frequency of 100 percent indicating that flow has equaled or exceeded this value 100 percent of the time, while the highest measured flow is found at an exceedance frequency of 0 percent. The median flow occurs at a flow exceedance frequency of 50 percent. The flow exceedance percentiles for each waterbody addressed in this report are provided in Appendix B.

While the number of observations required to develop a flow duration curve is not rigorously specified, a flow duration curve is usually based on more than 1 year of observations, and encompasses inter-annual and seasonal variation. Ideally, the drought of record and flood of record are included in the observations. For this purpose, the long-term flow gaging stations operated by the USGS are utilized (USGS 2007a) to support the Oklahoma TMDL Toolbox.

The USGS National Water Information System serves as the primary source of flow measurements for the Oklahoma TMDL Toolbox. All available daily average flow values for all gages in Oklahoma, as well as the nearest upstream and downstream gages in adjacent states, were retrieved for use in the Oklahoma TMDL Toolbox to generate flow duration curves for gaged and ungaged waterbodies. The application includes a data update module that automatically downloads the most recent USGS data and appends it to the existing flow database.

Some instantaneous flow measurements were available from various agencies. These were not combined with the daily average flows or used in calculating flow percentiles, but were matched to bacteria, turbidity, or TSS grab measurements collected at the same site and time. When available, these instantaneous flow measurements were used in lieu of projected flows to calculate pollutant loads.

A typical semi-log flow duration curve exhibits a sigmoidal shape, bending upward near a flow exceedance frequency value of 0 percent and downward at a frequency near 100 percent, often with a relatively constant slope in between. For sites that on occasion exhibit no flow, the curve will intersect the abscissa at a frequency less than 100 percent. As the number of observations at a site increases, the line of the LDC tends to appear smoother. However, at extreme low and high flow values, flow duration curves may exhibit a "stair step" effect due to the USGS flow data rounding conventions near the limits of quantitation. Figures 4-25 through 4-48 are flow duration curves for each impaired waterbody.

Figure 4-25 Flow Duration Curve for Deer Creek (OK311800000070_00)

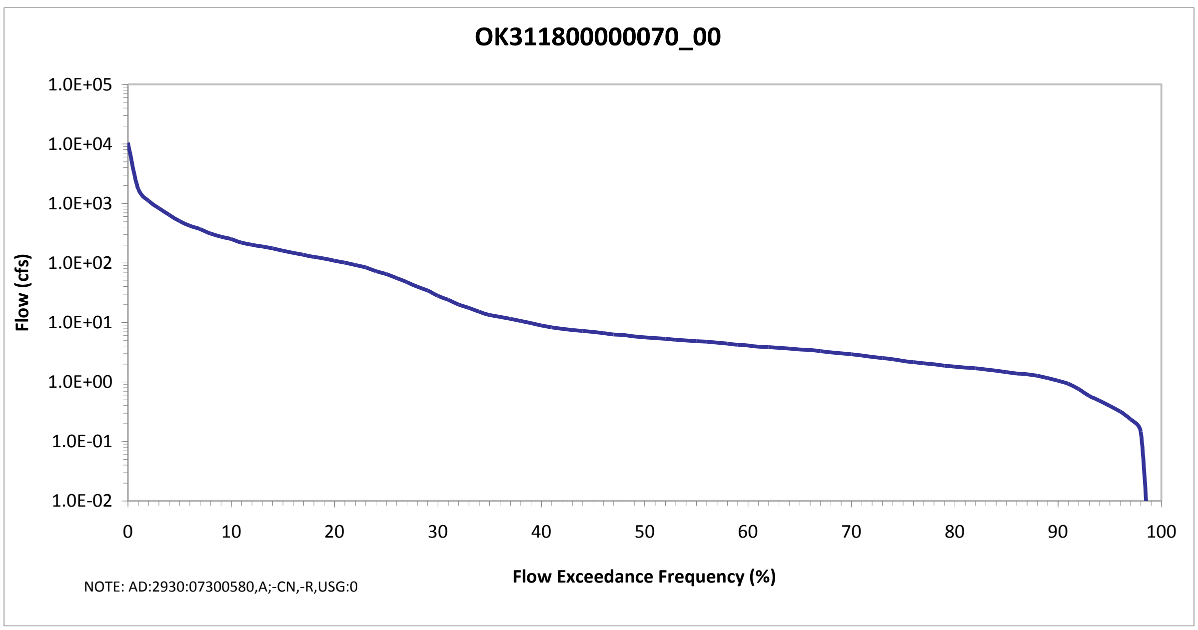


Figure 4-26 Flow Duration Curve for Haystack Creek (OK311800000040_00)

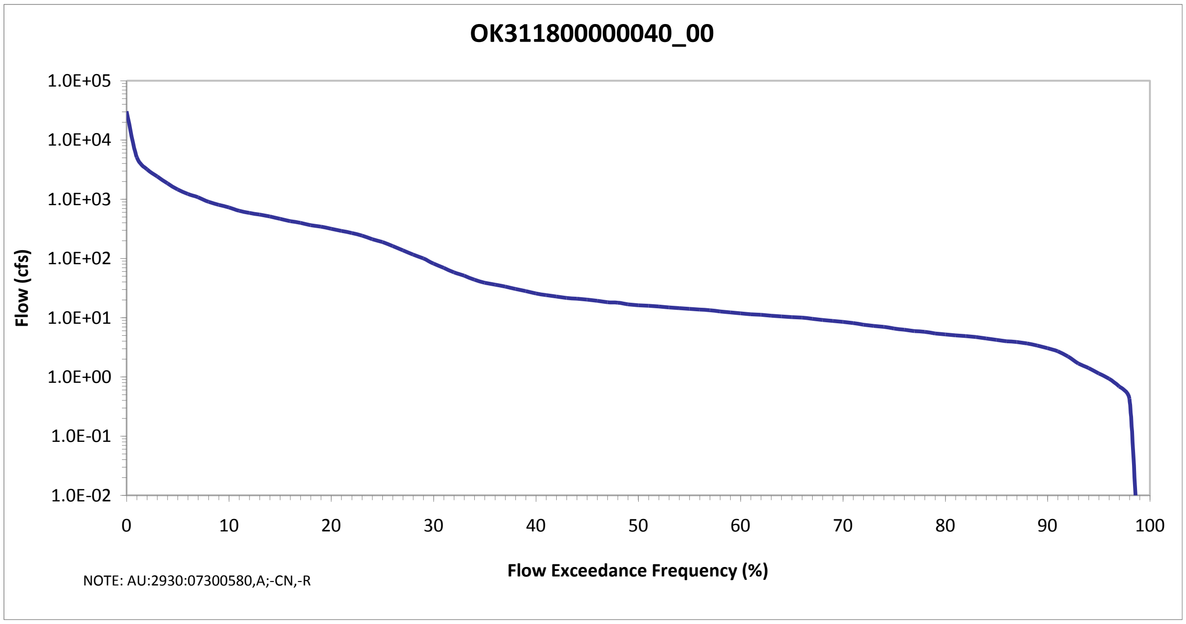


Figure 4-27 Flow Duration Curve for Sandy Creek (Lebos) (OK311600010040_00)

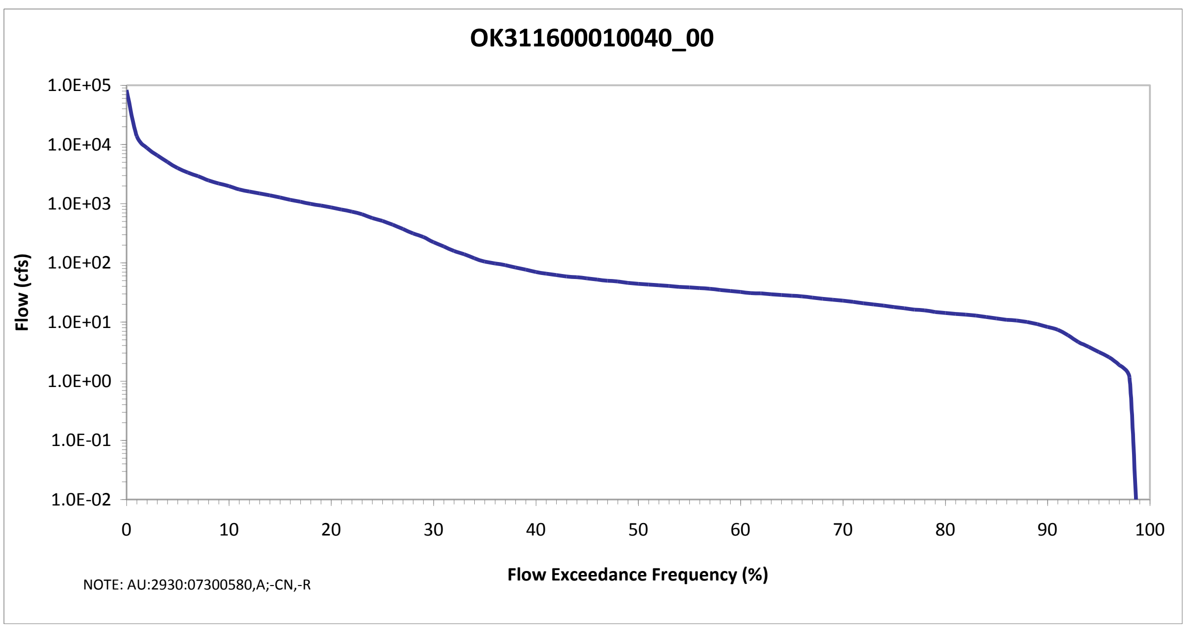


Figure 4-28 Flow Duration Curve for Gypsum Creek (OK311600010020_00)

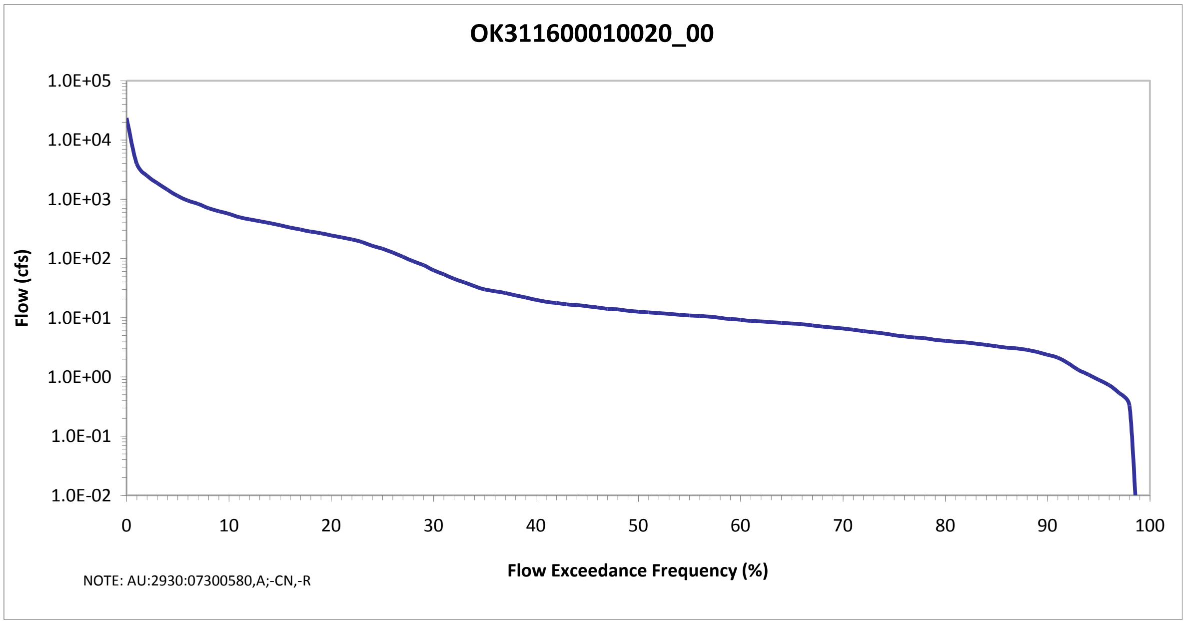


Figure 4-29 Flow Duration Curve for Sweetwater Creek (OK311510020120_00)

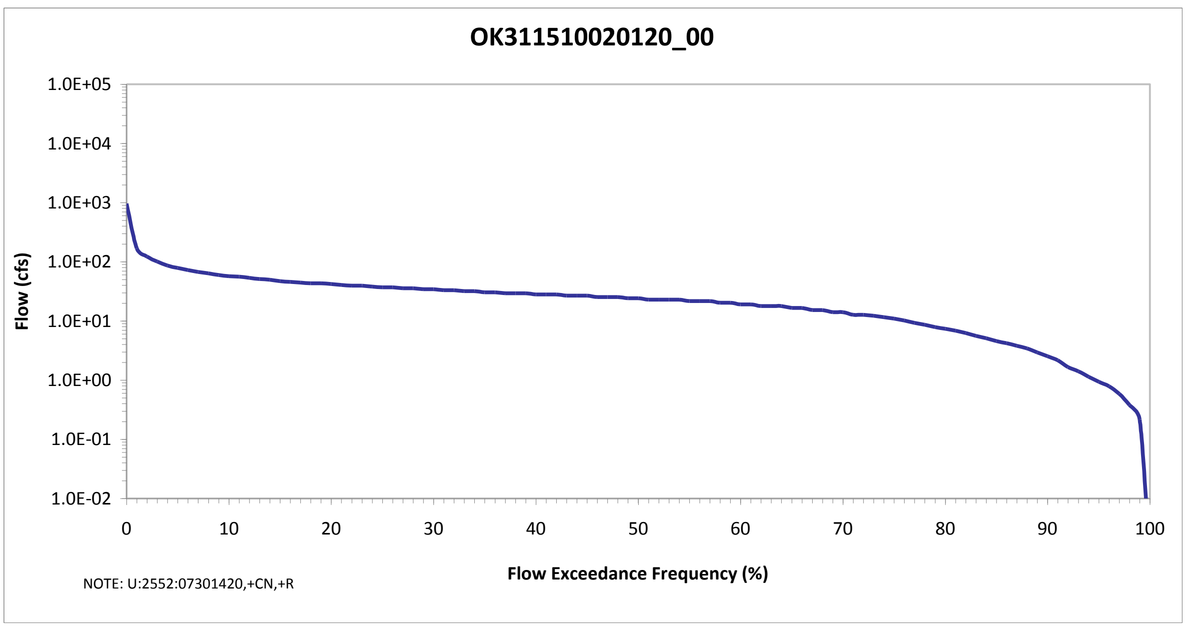


Figure 4-30 Flow Duration Curve for the Red River, North Fork, Carter (OK311510010010_10)

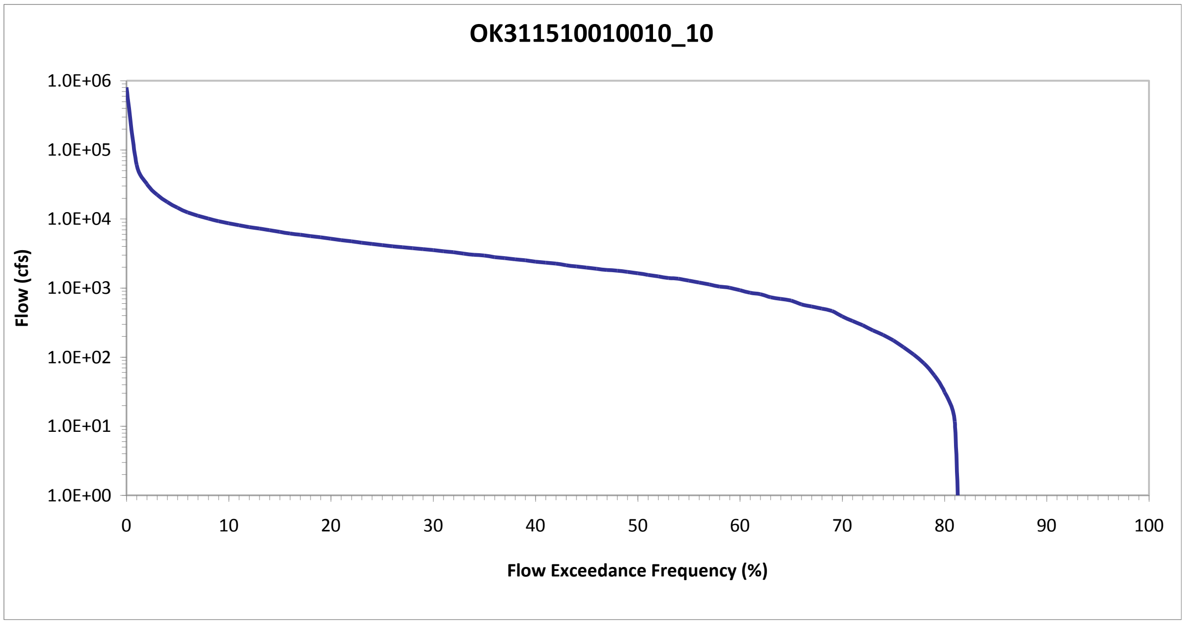


Figure 4-31 Flow Duration Curve for Elk Creek (OK311500030010_00)

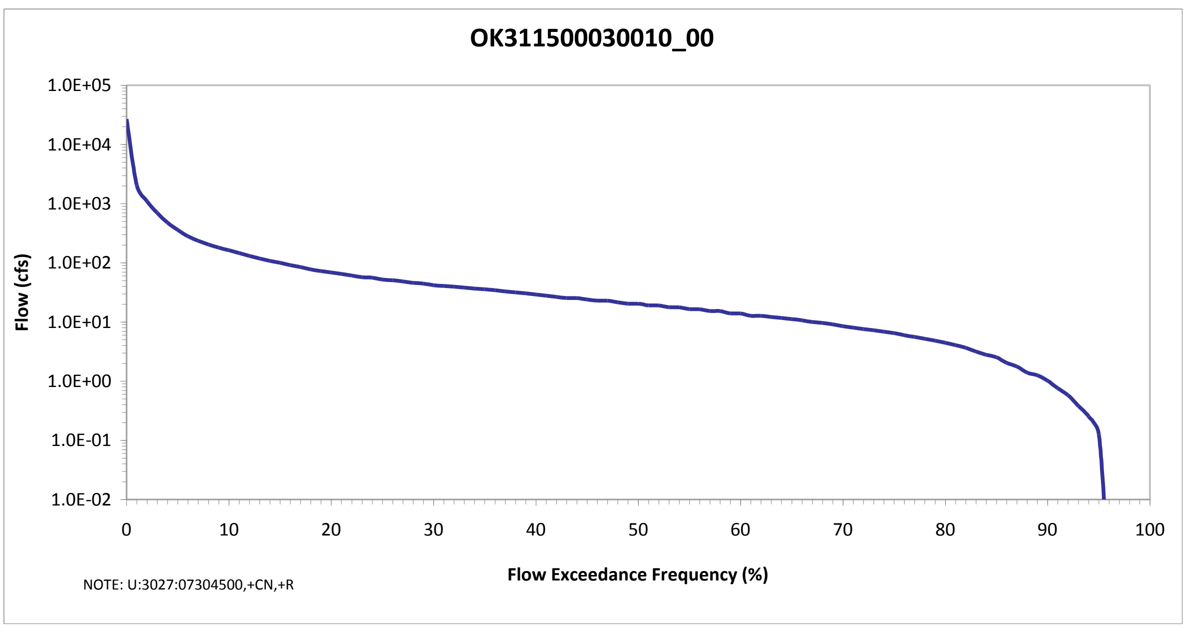


Figure 4-32 Flow Duration Curve for Otter Creek (OK311500010080_00)

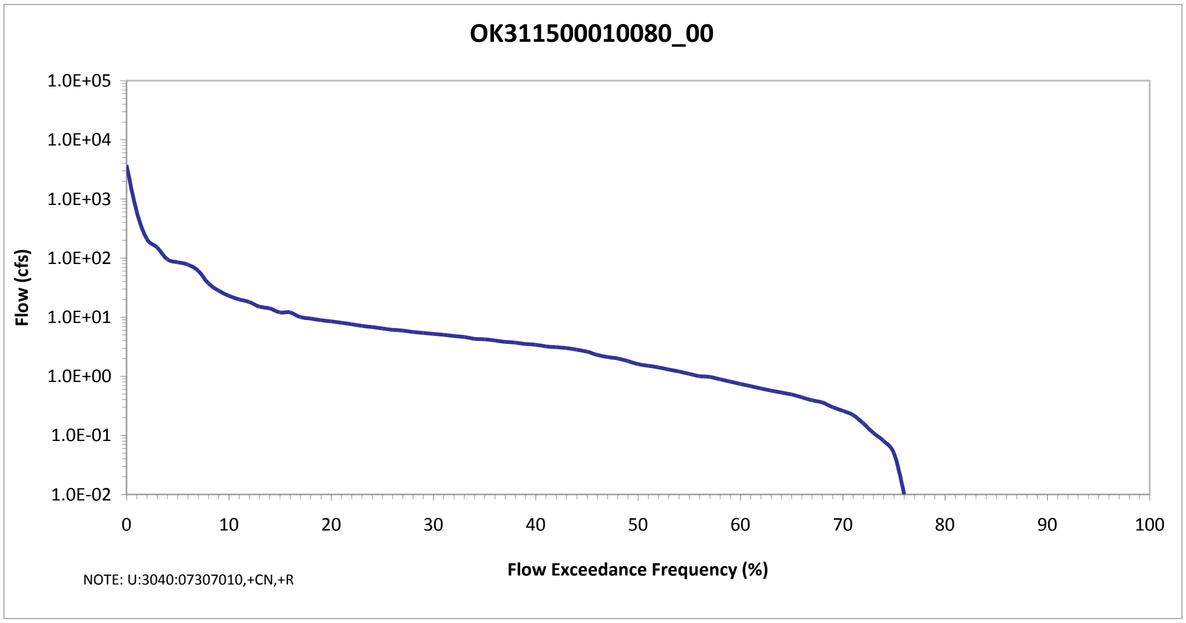


Figure 4-33 Flow Duration Curve for Stinking Creek (OK311500010050_00)

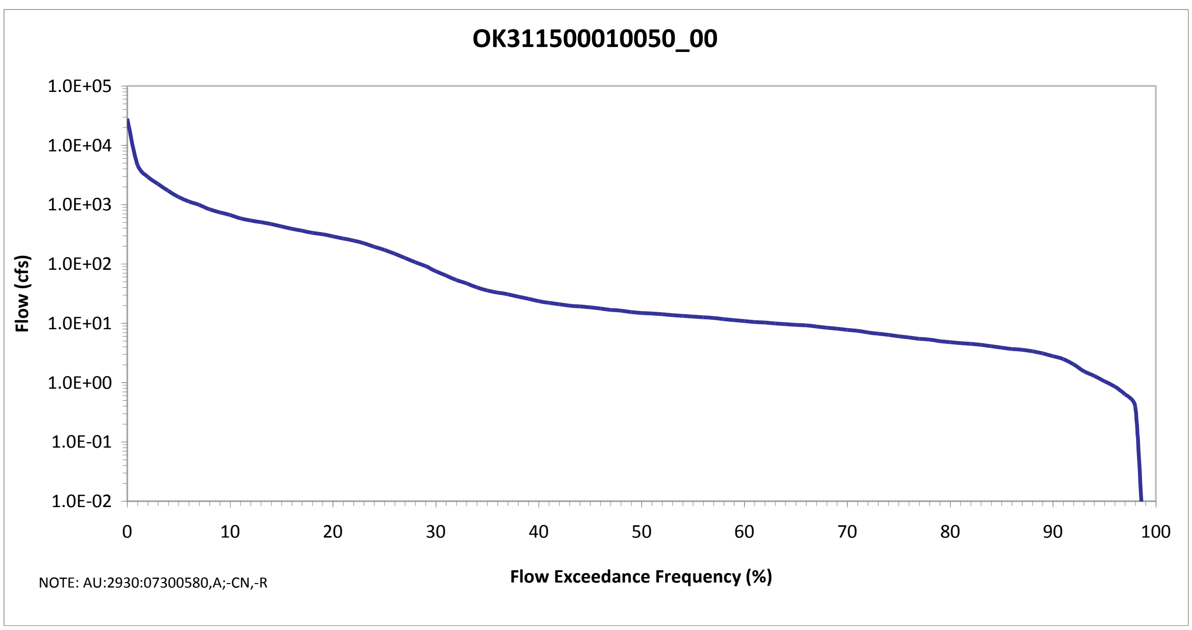


Figure 4-34 Flow Duration Curve for the Red River, North Fork, Headrick (OK311500010020_10)

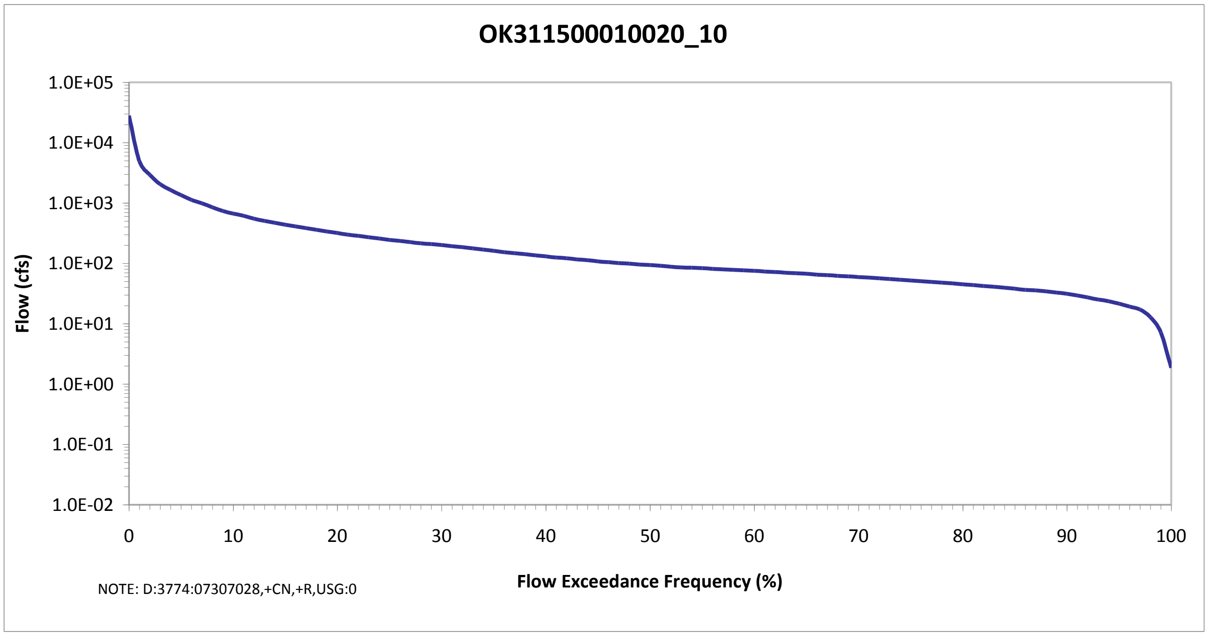


Figure 4-35 Flow Duration Curve for Brush Creek (OK311310030050_00)

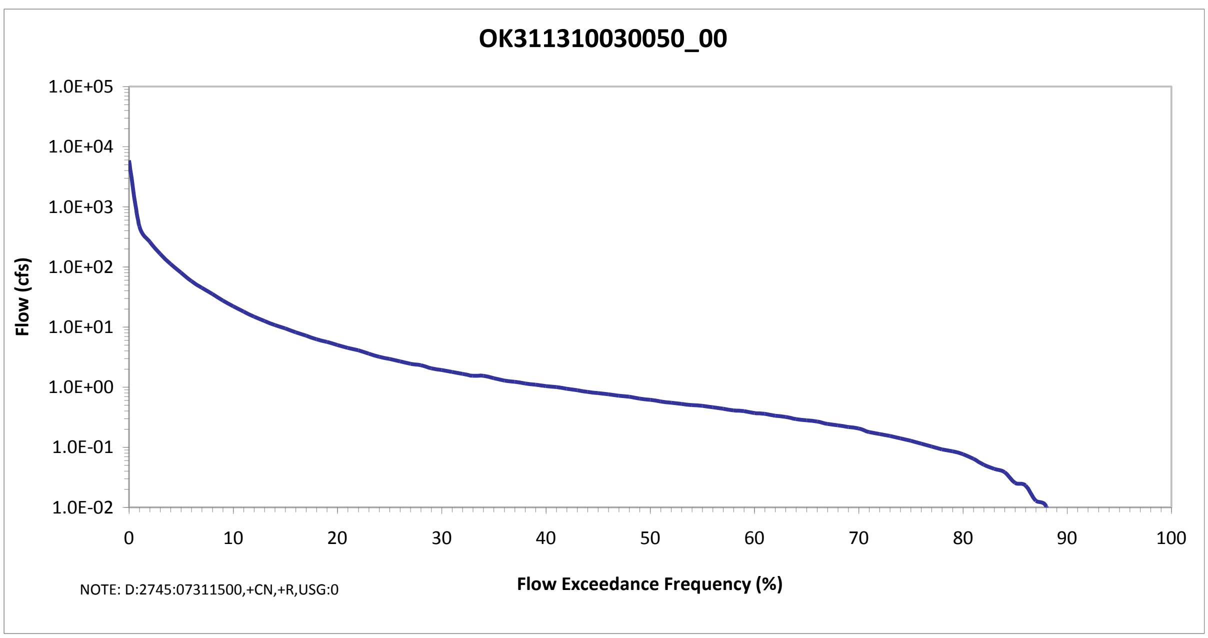


Figure 4-36 Flow Duration Curve for Little Deep Red Creek (OK311310030040_00)

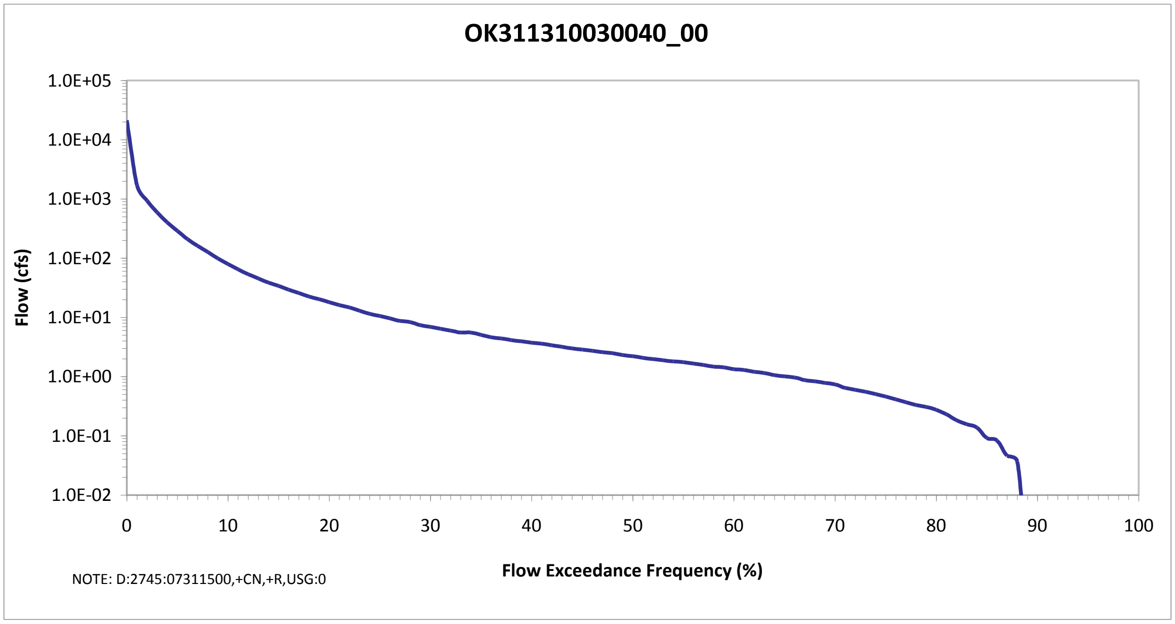


Figure 4-37 Flow Duration Curve for Deep Red Creek (OK311310030010_00)

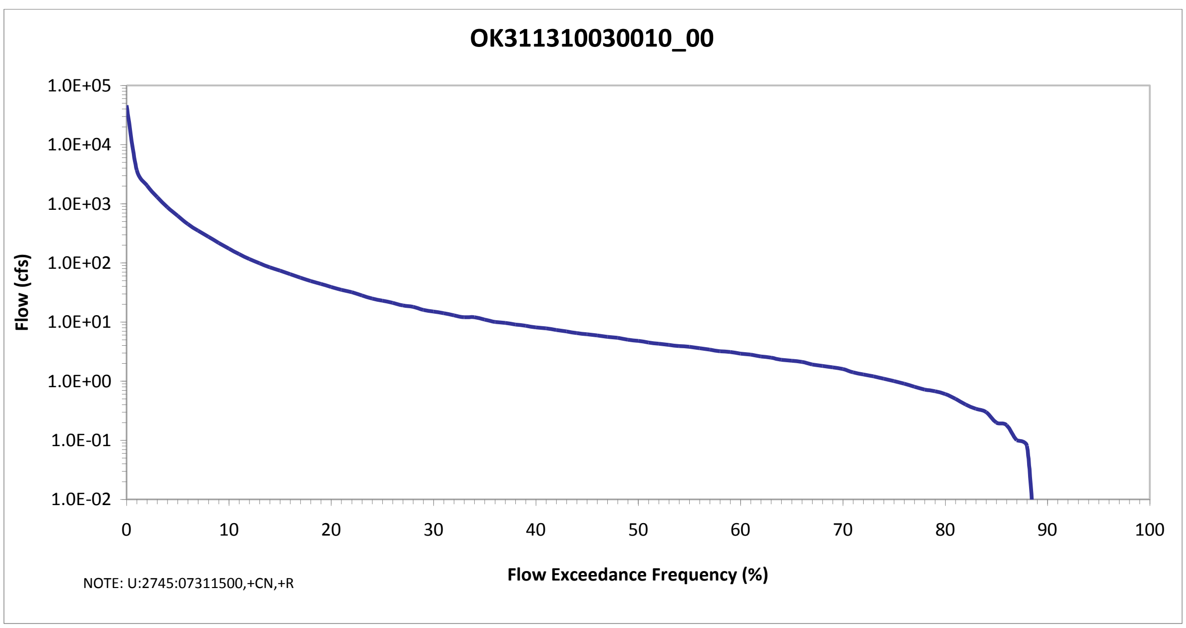


Figure 4-38 Flow Duration Curve for West Cache Creek (OK311310020010_00)

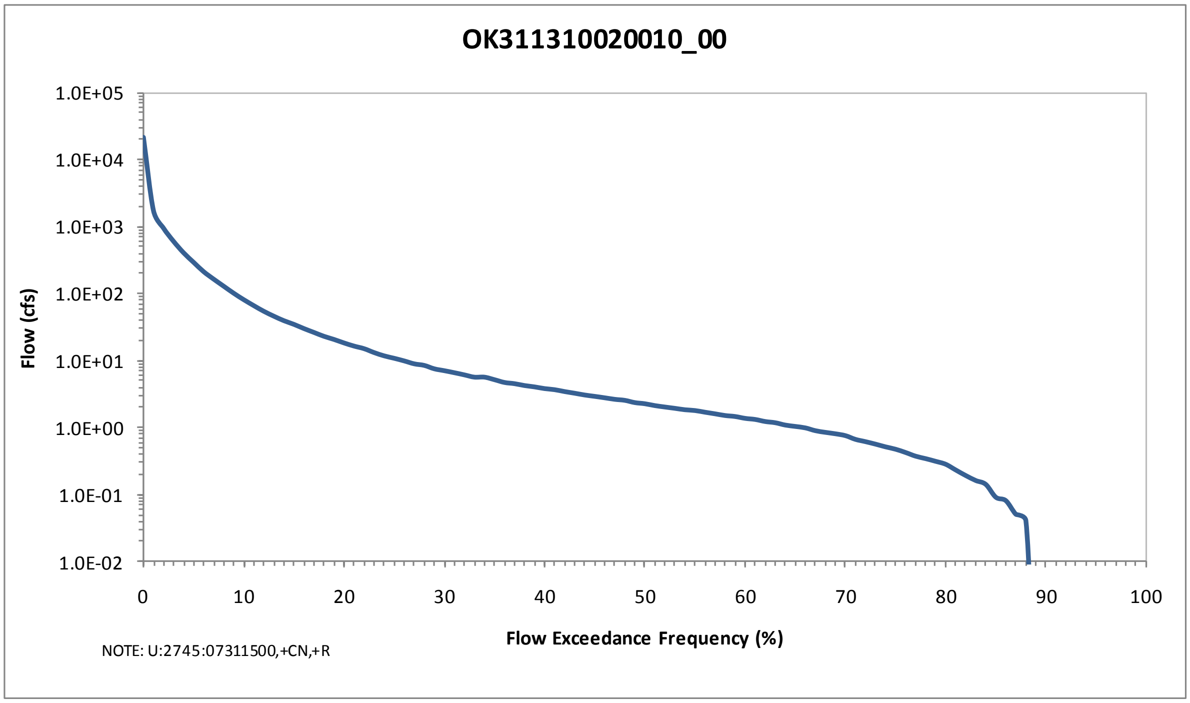


Figure 4-39 Flow Duration Curve for Suttle Creek (OK311310010070_00)

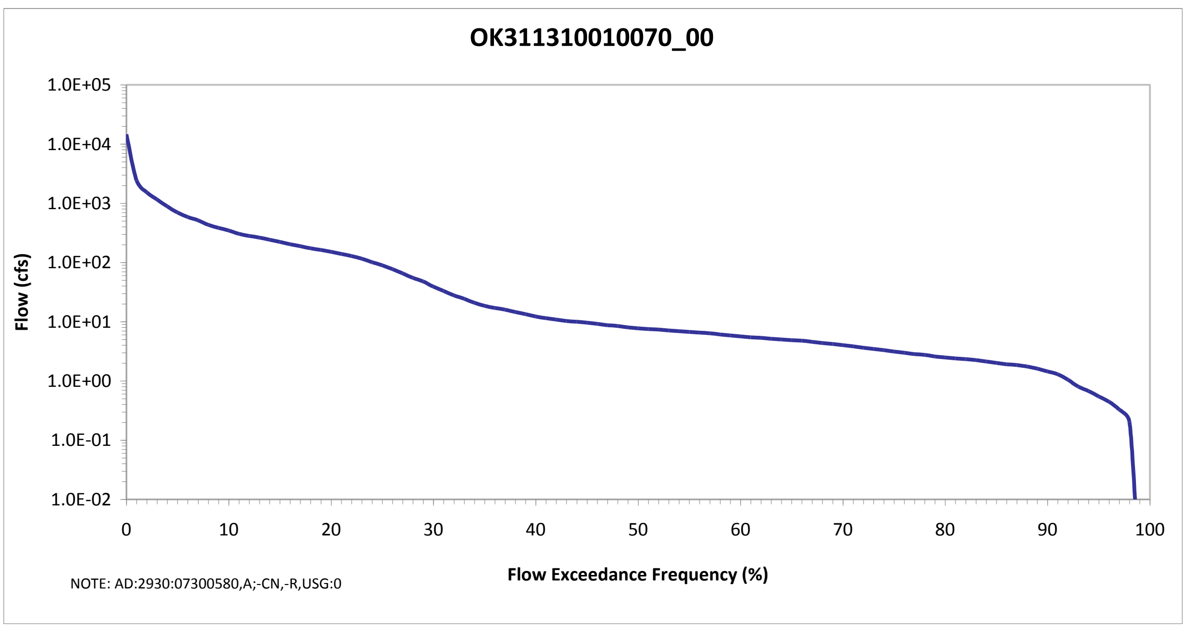


Figure 4-40 Flow Duration Curve for East Cache Creek, Walters (OK311300010020_10)

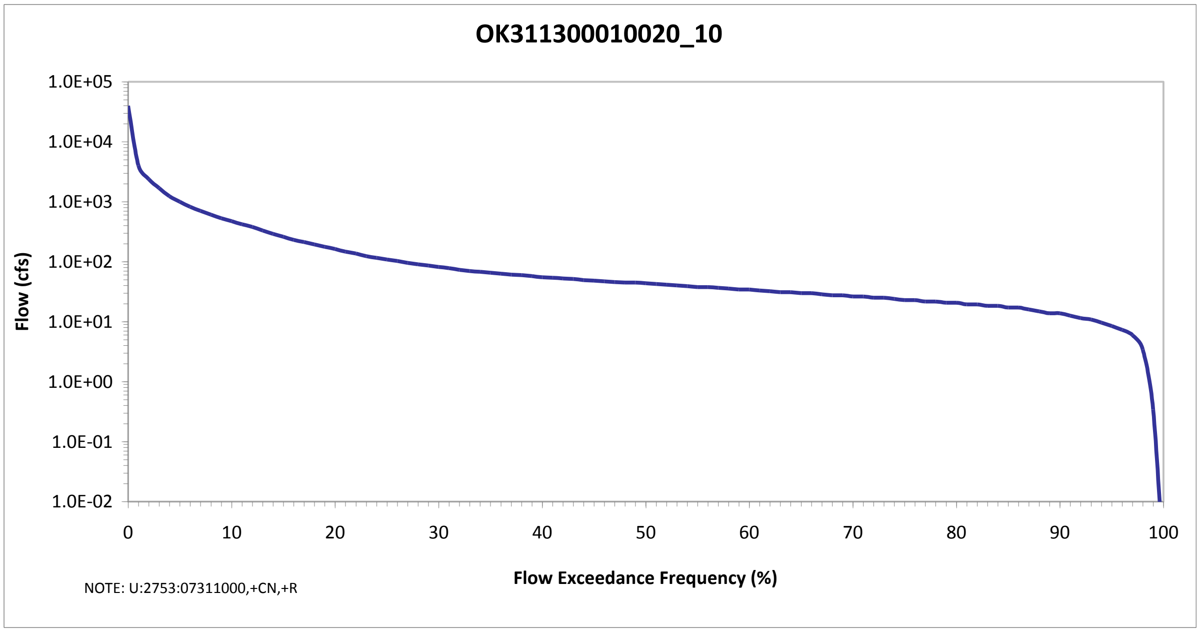


Figure 4-41 Flow Duration Curve for East Cache Creek (OK311300010020_00)

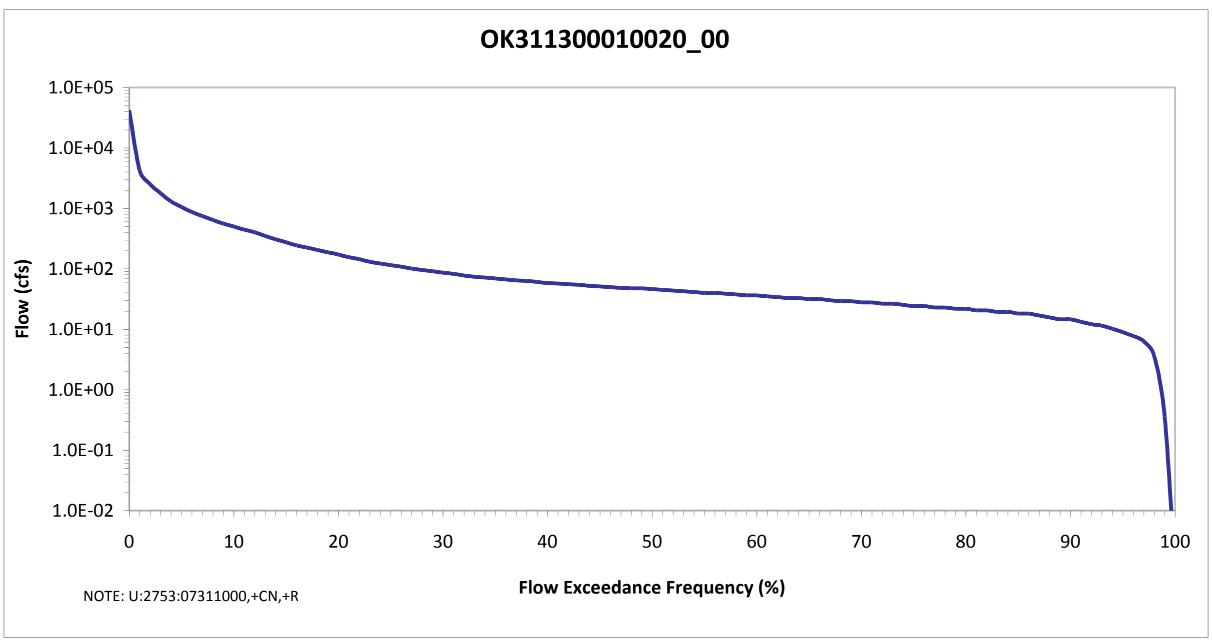


Figure 4-42 Flow Duration Curve for Dry Creek (OK311200000080_00)

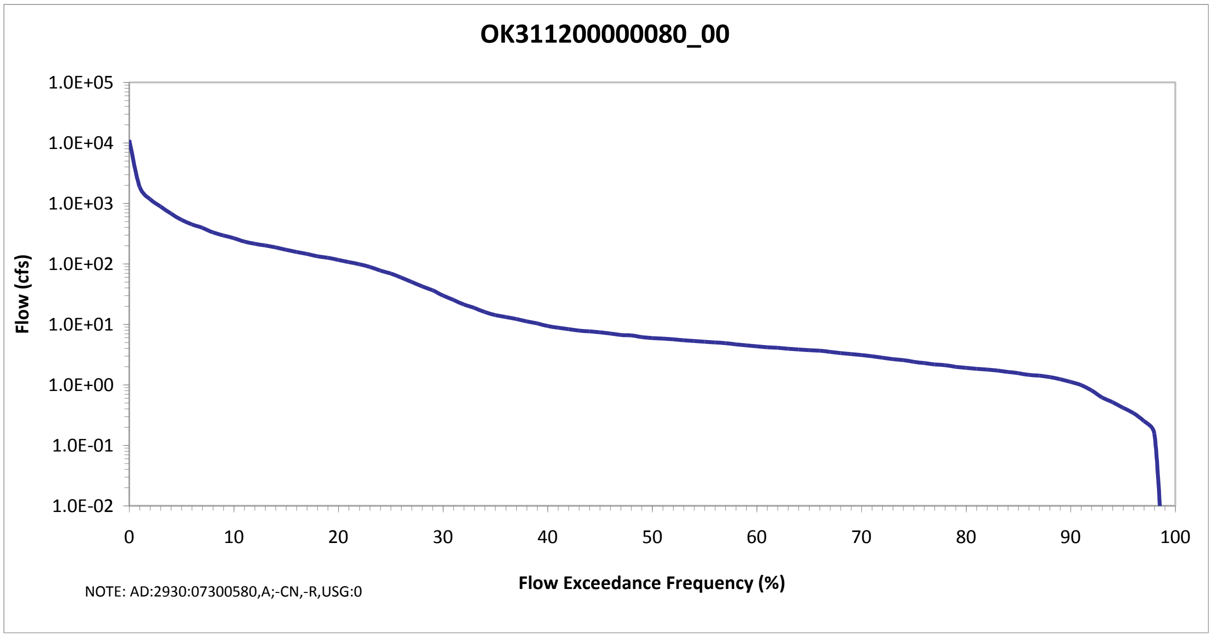


Figure 4-43 Flow Duration Curve for Cow Creek (OK311200000060_00)

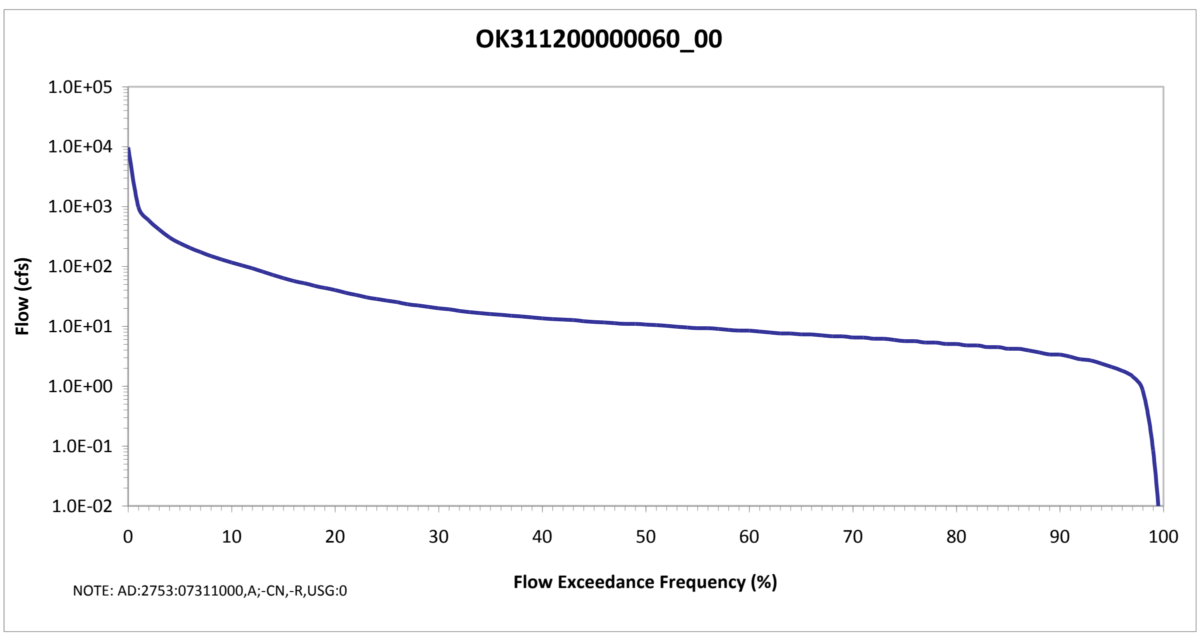


Figure 4-44 Flow Duration Curve for Beaver Creek (OK311200000030_00)

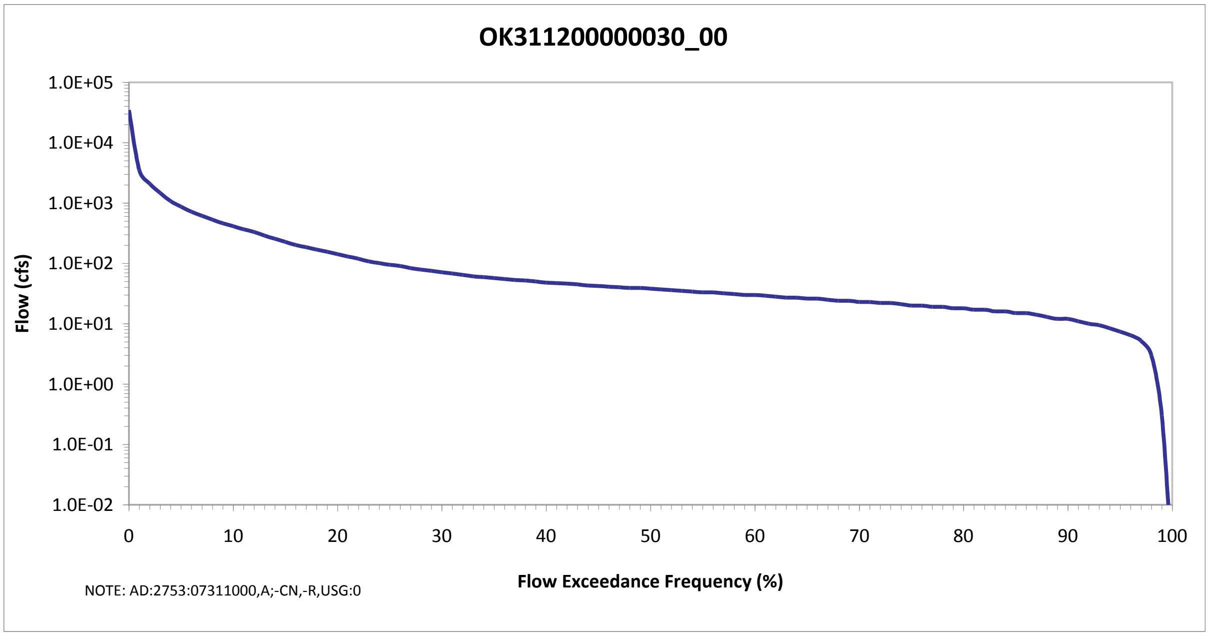


Figure 4-45 Flow Duration Curve for Mud Creek, Lower West (OK311100040080_00)

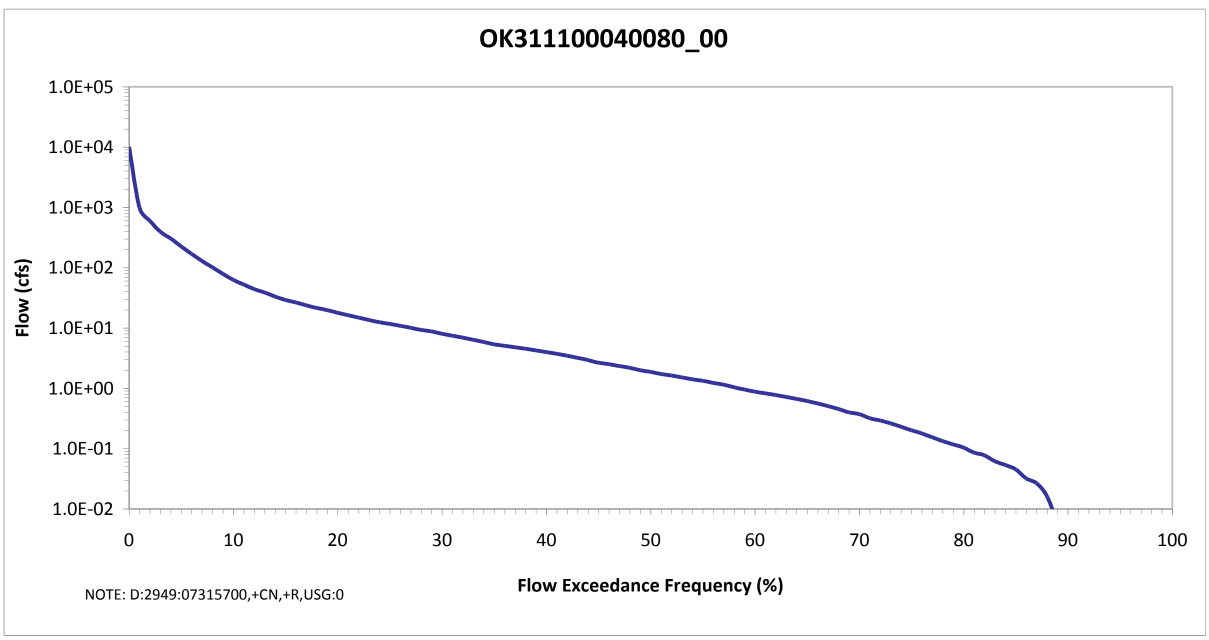


Figure 4-46 Flow Duration Curve for Mud Creek (OK311100040010_00)

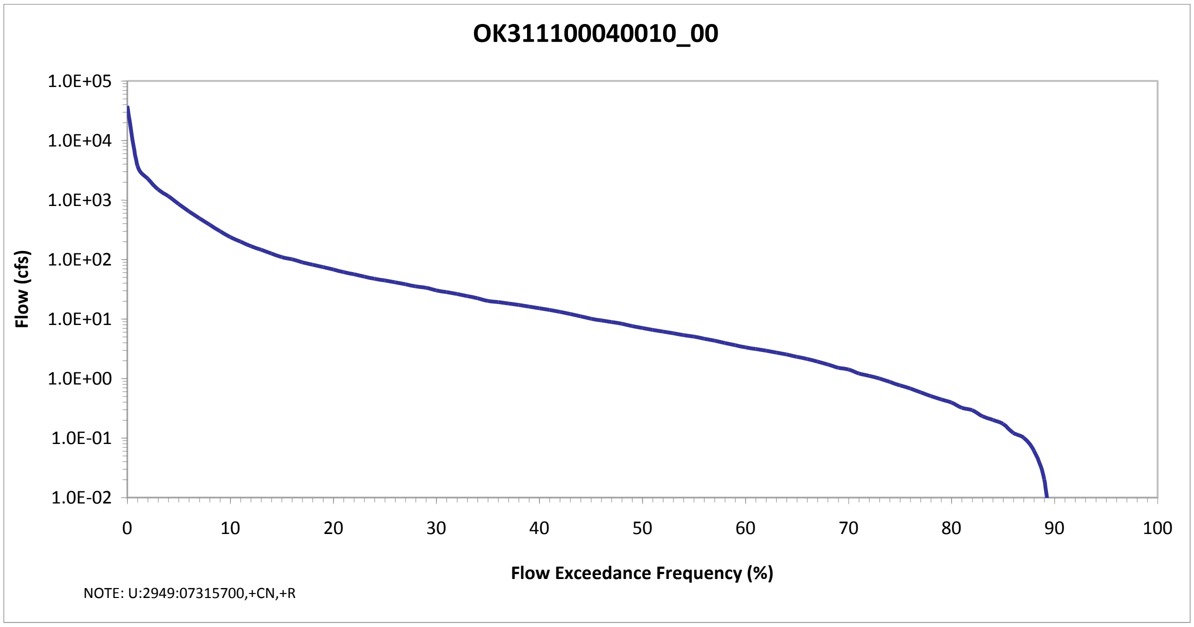


Figure 4-47 Flow Duration Curve for Fleetwood Creek (OK311100010300_00)

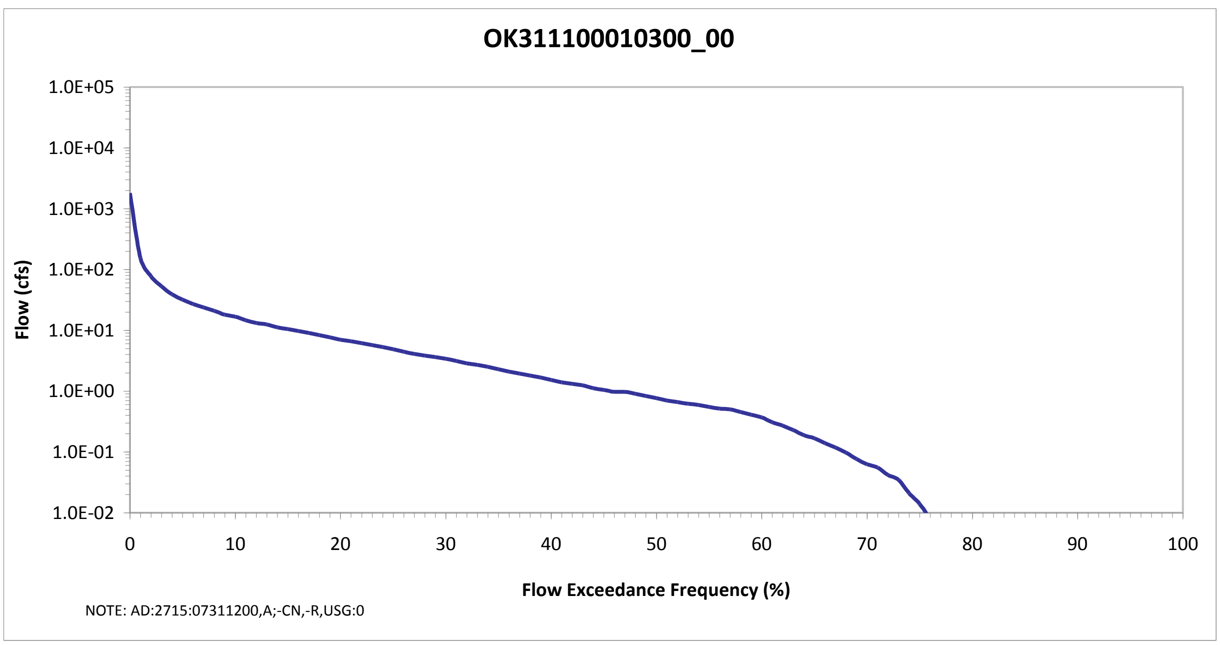
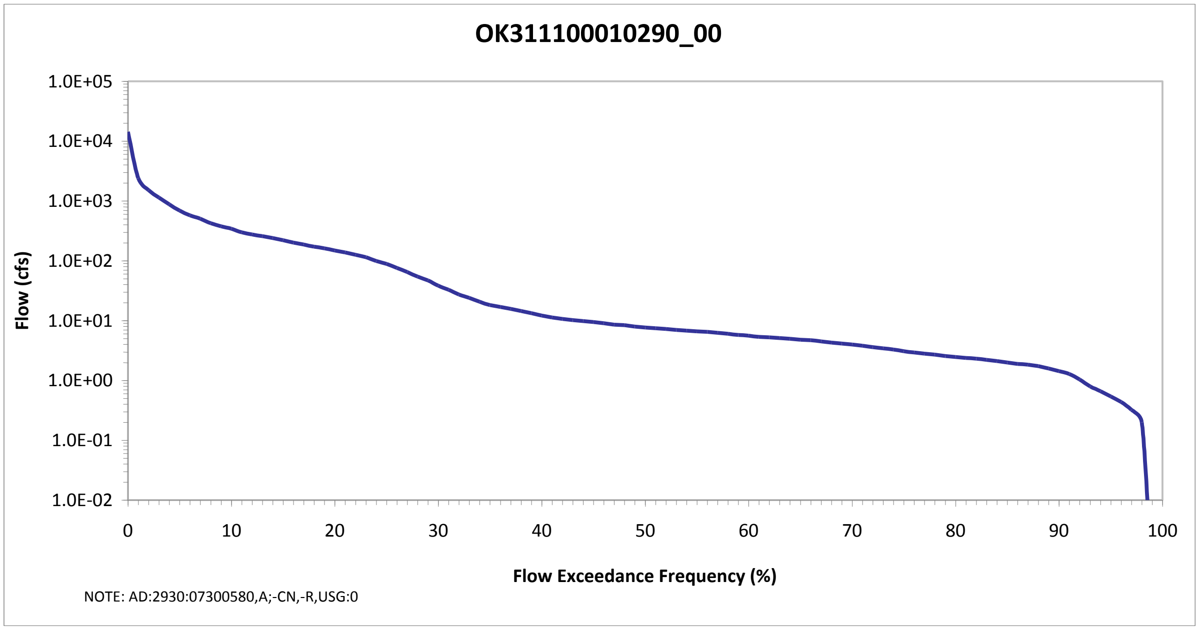


Figure 4-48 Flow Duration Curve for Red Creek (OK311100010290_00)



4.4 Estimating Existing Loading

A key step in the use of LDCs for TMDL development is the estimation of existing instream loads. This is accomplished by:

- matching the water quality observations with the flow data from the same date;
- converting measured concentration values to loads by multiplying the flow at the time the sample was collected by the water quality parameter concentration (for sampling events with both TSS and turbidity data, the measured TSS value is used; if only turbidity was measured, the value was converted to TSS using the regression equations described); or multiplying the flow by the bacteria indicator concentration to calculate daily loads.

4.5 Development of TMDLs Using Load Duration Curves

The final step in the TMDL calculation process involves a group of additional computations derived from the preparation of LDCs. These computations are necessary to derive a PRG (which is one method of presenting how much pollutant loads must be reduced to meet WQSs in the impaired watershed).

Step 1: Generate Bacteria LDCs. LDCs are similar in appearance to flow duration curves; however, for bacteria the ordinate is expressed in terms of a bacteria load in cfu/day, and for TSS the ordinate is expressed in terms of a load in lbs/day. The curve represents the single sample water quality criterion for fecal coliform (400 cfu/100 mL), *E. coli* (406 cfu/100 mL), or Enterococci (108 cfu/100 mL) expressed in terms of a load through multiplication by the continuum of flows historically observed at the site. For turbidity, the curve represents the water quality target for TSS from Table 4-1 expressed in terms of a load obtained through multiplication of the TSS goal by the continuum of flows historically observed at the site. The basic steps to generating an LDC involve:

- obtaining daily flow data for the site of interest from the USGS;
- sorting the flow data and calculating flow exceedance percentiles for the time period and season of interest;
- obtaining the water quality data from the primary contact recreation season (May 1 through September 30); or obtaining available turbidity and TSS water quality data;
- displaying a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQS for each respective bacteria indicator; or displaying a curve on a plot that represents the allowable load determined by multiplying the actual or estimated flow by the WQ_{goal} for TSS;
- matching the water quality observations with the flow data from the same date and determining the corresponding exceedance percentile;
- plotting the flow exceedance percentiles and daily load observations in a load duration plot (See Section 5).

For bacteria TMDLs the culmination of these steps is expressed in the following formula, which is displayed on the LDC as the TMDL curve:

TMDL (cfu/day) = WQS * flow (cfs) * unit conversion factor

Where: WQS = 400 cfu /100 mL (Fecal coliform); 406 cfu/100 mL (E. coli); or 108 cfu/100 mL (Enterococci)

unit conversion factor = 24,465,525 mL*s / ft3*day

For turbidity (TSS) TMDLs the culmination of these steps is expressed in the following formula, which is displayed on the LDC as the TMDL curve:

TMDL (lb/day) = WQ_{goal} * flow (cfs) * unit conversion factor

where: WQ_{goal} = waterbody specific TSS concentration derived from regression analysis results presented in Table 4-1

unit conversion factor = 5.39377 L*s*lb /(ft^3*day*mg)

The flow exceedance frequency (x-value of each point) is obtained by looking up the historical exceedance frequency of the measured or estimated flow, in other words, the percent of historical observations that equal or exceed the measured or estimated flow. Historical observations of bacteria, TSS and/or turbidity concentrations are paired with flow data and are plotted as separate LDCs. The fecal coliform load (or the y-value of each point) is calculated by multiplying the fecal coliform concentration (colonies/100 mL) by the instantaneous flow (cubic feet per second) at the same site and time, with appropriate volumetric and time unit conversions. Fecal coliform/*E. coli*/Enterococci loads representing exceedance of water quality criteria fall above the water quality criterion line. Likewise, the TSS load (or the y-value of each point) is calculated by multiplying the TSS concentration (measured or converted from turbidity) (mg/L) by the instantaneous flow (cfs) at the same site and time, with appropriate volumetric and time unit conversions. TSS loads representing exceedance of water quality criteria fall above the TMDL line. Regarding bacteria data, it is noted that only those flows and water quality samples observed in the months comprising the primary contact recreation season are used to generate the LDCs. It is inappropriate to compare single sample bacteria observations and instantaneous or daily flow durations to a 30-day geometric mean water quality criterion in the LDC.

As noted earlier, runoff has a strong influence on loading of nonpoint pollution. Yet flows do not always correspond directly to runoff; high flows may occur in dry weather and runoff influence may be observed with low or moderate flows.

Step 2: Define MOS. The MOS may be defined explicitly or implicitly. A typical explicit approach would reserve some specific fraction of the TMDL as the MOS. In an implicit approach, conservative assumptions used in developing the TMDL are relied upon to provide an MOS to assure that WQSs are attained. For bacteria TMDLs in this report, an explicit MOS of 10 percent was selected. The 10 percent MOS has been used in other approved bacteria TMDLs. For turbidity (TSS) TMDLs an explicit MOS is derived from the NRMSE established by the turbidity/TSS regression analysis conducted for each waterbody. This approach for setting an explicit MOS has been used in other approved turbidity TMDLs.

Step 3: Calculate WLA. As previously stated, the pollutant load allocation for point sources is defined by the WLA. For bacteria TMDLs a point source can be either a wastewater (continuous) or stormwater (MS4) discharge. Stormwater point sources are typically associated with urban and industrialized areas, and recent USEPA guidance includes NPDES-permitted stormwater discharges as point source discharges and, therefore, part of the WLA. For TMDL development purposes when addressing turbidity or TSS, a WLA will be established for wastewater (continuous) discharges in impaired watersheds that do not have a BOD or CBOD permit limit but do have a TSS limit. These point source discharges of inorganic suspended solids will be assigned a TSS WLA as part of turbidity TMDLs to ensure WQS can be maintained. As discussed in Section 3.1 a WLA for TSS is not necessary for MS4s.

The LDC approach recognizes that the assimilative capacity of a waterbody depends on the flow, and that maximum allowable loading will vary with flow condition. TMDLs can be expressed in terms of maximum allowable concentrations, or as different maximum loads allowable under different flow conditions, rather than single maximum load values. For bacteria TMDLs a concentration-based approach meets the requirements of 40 CFR, 130.2(i) for expressing TMDLs "in terms of mass per time, toxicity, or other appropriate measures" and is consistent with USEPA's Protocol for Developing Pathogen TMDLs (USEPA 2001). For turbidity (TSS) TMDLs a load-based approach also meets the requirements of 40 CFR, 130.2(i) for expressing TMDLs "in terms of mass per time, toxicity, or other appropriate measures."

WLA for WWTP. WLAs may be set to zero in cases of watersheds with no existing or planned continuous permitted point sources. For watersheds with permitted point sources, NPDES permit limits are used to derive WLAs. The permitted flow rate used for each point source discharge and the water quality concentration defined in a permit are used to estimate the WLA for each wastewater facility. In cases where a permitted flow rate is not available for a WWTP, then the average of monthly flow rates derived from DMRs can be used. WLA values for each NPDES wastewater discharger are then summed to represent the total WLA for a given watershed. Using this information bacteria and TSS WLAs can be calculated using a mass balance approach as shown in the equations below.

WLA for bacteria:

WLA = WQS * flow * unit conversion factor (#/day)

Where:

WQS = 200 cfu /100 mL (Fecal coliform); 126 cfu/100 mL (E. coli); or 33 cfu/100 mL (Enterococci)

flow (10^6 gal/day) = permitted flow

unit conversion factor = 37,854,120-10^6gal/day

WLA for TSS:

WLA = WQ goal * flow * unit conversion factor (lb/day)

Where:

WQ goal is provided in Table 4-1;

flow (10^6 gal/day) = permitted flow or average monthly flow

unit conversion factor = 8.3445 L*lb/(gal*mg)

Step 4: Calculate LA and WLA for MS4s. Given the lack of data and the variability of storm events and discharges from storm sewer system discharges, it is difficult to establish numeric limits on stormwater discharges that accurately address projected loadings. As a result, EPA regulations and guidance recommend expressing NPDES permit limits for MS4s as BMPs.

LAs can be calculated under different flow conditions as the water quality target load minus the WLA. The LA is represented by the area under the LDC but above the WLA. The LA at any particular flow exceedance is calculated as shown in the equation below.

LA = TMDL - WLA_WWTP - WLA_MS4 - MOS

WLA for MS4s. For bacteria TMDLs, if there are no permitted MS4s in the study area, WLA_MS4 is set to zero. When there are permitted MS4s in the watershed, we can first calculate the sum of LA + WLA_MS4 using the above formula, then separate WLA for MS4s from the sum based on the percentage of a watershed that is under a MS4 jurisdiction. This WLA for MS4s may not be the total load allocated for permitted MS4s unless the whole MS4 area is located within the study watershed boundary. However, in most case the study watershed intersects only a portion of the permitted MS4 coverage areas.

For turbidity TMDLs, WLAs for permitted stormwater such as MS4s, construction, and multi-sector general permits are not calculated since these discharges occur under high flow conditions when the turbidity criteria do not apply.

Step 5: Estimate WLA Load Reduction. The WLA load reduction for bacteria was not calculated as it was assumed that continuous dischargers (NPDES-permitted WWTPs) are adequately regulated under existing permits to achieve water quality standards at the end-of-pipe and, therefore, no WLA reduction would be required. If there are no MS4s located within the Study Area requiring a TMDL then there is no need to establish a PRG for permitted stormwater.

The WLA load reduction for TSS for dischargers without BOD/CBOD limits can be determined as follows:

If permitted TSS limit is less than TSS goal for the receiving stream, there will be no reductions;

If permitted TSS limit is greater than TSS goal for the receiving stream, the permit limit will be set at the TSS goal.

Step 6: Estimate LA Load Reduction. After existing loading estimates are computed for each pollutant, nonpoint load reduction estimates for each WQM station are calculated by using the difference between estimated existing loading and the allowable load expressed by the LDC (TMDL-MOS). This difference is expressed as the overall PRG for the impaired waterbody. For fecal coliform the PRG which ensures that no more than 25 percent of the samples exceed the TMDL based on the instantaneous criteria allocates the loads in manner that is also protective of the geometric mean criterion. For *E. coli* and Enterococci, because WQSs are considered to be met if 1) either the geometric mean of all data is less than the geometric mean criteria, or 2) no sample exceeds the instantaneous criteria, the TMDL PRG will be the lesser of that required to meet the geometric mean or instantaneous criteria. For turbidity, the PRG is the load reduction that ensures that no more than 10 percent of the samples under flow-base conditions exceed the TMDL.

SECTION 5
TMDL CALCULATIONS

5.1 Estimated Loading and Critical Conditions

USEPA regulations at 40 CFR 130.7(c) (1) require TMDLs to take into account critical conditions for stream flow, loading, and all applicable water quality standards. To accomplish this, available instream WQM data were evaluated with respect to flows and magnitude of water quality criteria exceedance using LDCs.

Bacteria LDC: To calculate the bacteria load, the flow rate at each flow exceedance percentile is multiplied by a unit conversion factor (*24,465,525 mLs / ft*^{3} *day*) and the criterion specific to each bacterial indicator. This calculation produces the maximum bacteria load in the stream without exceeding the instantaneous standard over the range of flow conditions. The allowable bacteria (fecal coliform, *E. coli*, or Enterococci) loads at the WQS establish the TMDL and are plotted versus flow exceedance percentile as a LDC. The x-axis indicates the flow exceedance percentile, while the y-axis is expressed in terms of a bacteria load.

To estimate existing loading, bacteria observations for the primary contact recreation season (May 1st through September 30th) from 2002 to 2009 are paired with the flows measured or estimated in that waterbody on the same date. Pollutant loads are then calculated by multiplying the measured bacteria concentration by the flow rate and the unit conversion factor of *24,465,756 mLs / ft*^{3} *day*. The associated flow exceedance percentile is then matched with the measured flow from the tables provided in Appendix B. The observed bacteria loads are then added to the LDC plot as points. These points represent individual ambient water quality samples of bacteria. Points above the LDC indicate the bacteria instantaneous standard was exceeded at the time of sampling. Conversely, points under the LDC indicate the sample met the WQS.

The bacteria LDCs developed for each impaired waterbody (representing the primary contact recreation season from 2002 through 2009) are shown in Figures 5-1 through 5-16. Waterbodies may have more than one LDC because for the PBCR use to be supported, criteria for each bacterial indicator must be met in each impaired waterbody.

The LDCs for Haystack Creek (Figures 5-1 and 5-2) are based on *E. coli* and Enterococci bacteria measurements collected during primary contact recreation season at WQM station OK311800-00-0040D. The LDCs indicate that levels of both bacterial indicators sometimes exceed the instantaneous water quality criteria under low and moderate flow conditions.

Figure 5-1 Load Duration Curve for *E. coli* in Haystack Creek (OK311800000040_00)

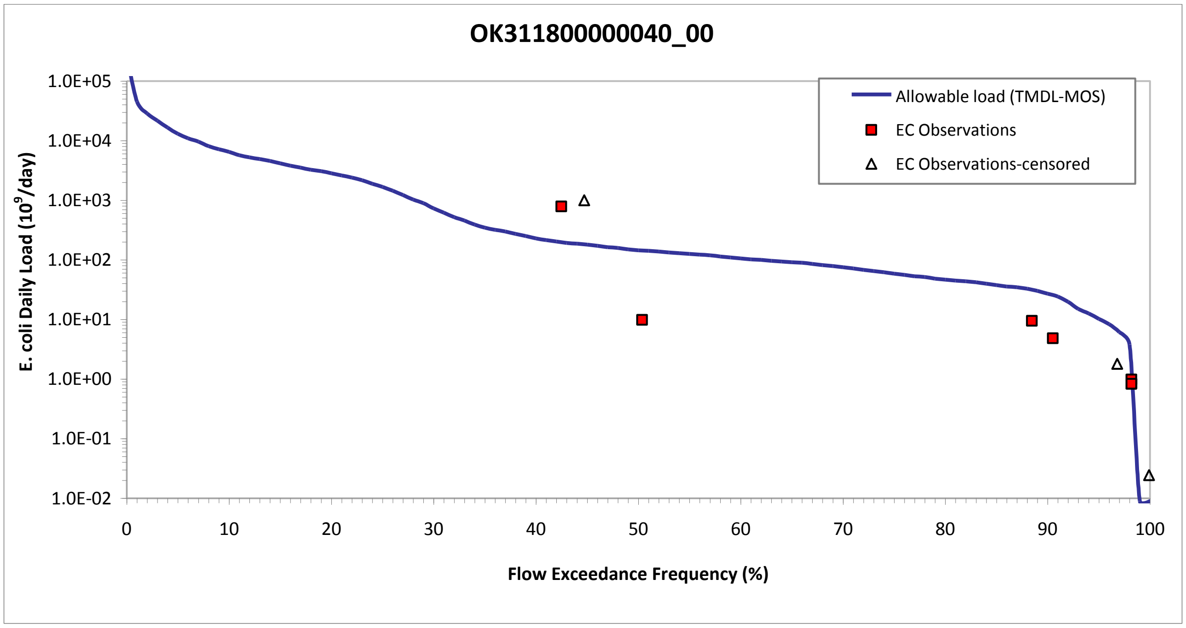
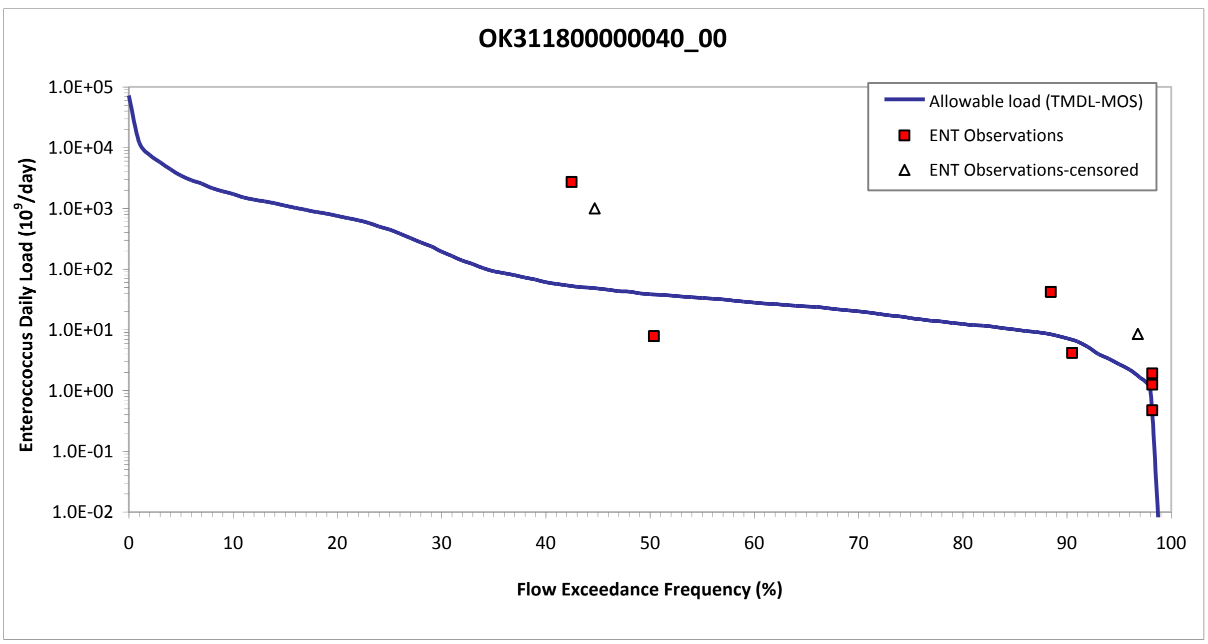
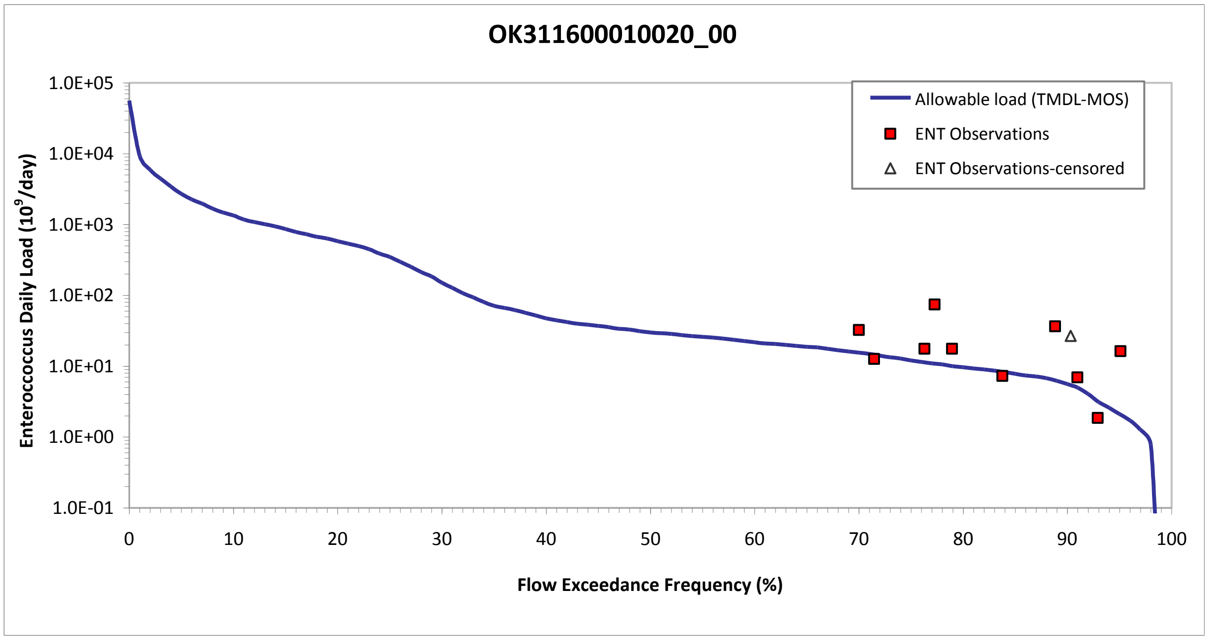


Figure 5-2 Load Duration Curve for Enterococci in Haystack Creek (OK311800000040_00)



The LDC for Gypsum Creek (Figure 5-3) is based on Enterococci measurements during primary contact recreation season at WQM station 311600-01-0020F. The LDC indicates that Enterococci levels exceed the instantaneous water quality criteria under low flow conditions.

Figure 5-3 Load Duration Curve for Enterococci in Gypsum Creek (OK311600010020_00)



The LDCs for Sweetwater Creek (Figures 5-4 and 5-5) are based on *E. coli* and Enterococci bacteria measurements collected during primary contact recreation season at WQM station OK311510-02-0120D. The LDCs indicate that levels of *E. coli* sometimes exceed the instantaneous water quality criteria under low and high flow conditions. Levels of Enterococci typically exceed the instantaneous water quality criteria under low flow conditions.

Figure 5-4 Load Duration Curve for *E. coli* in Sweetwater Creek (OK311510020120_00)

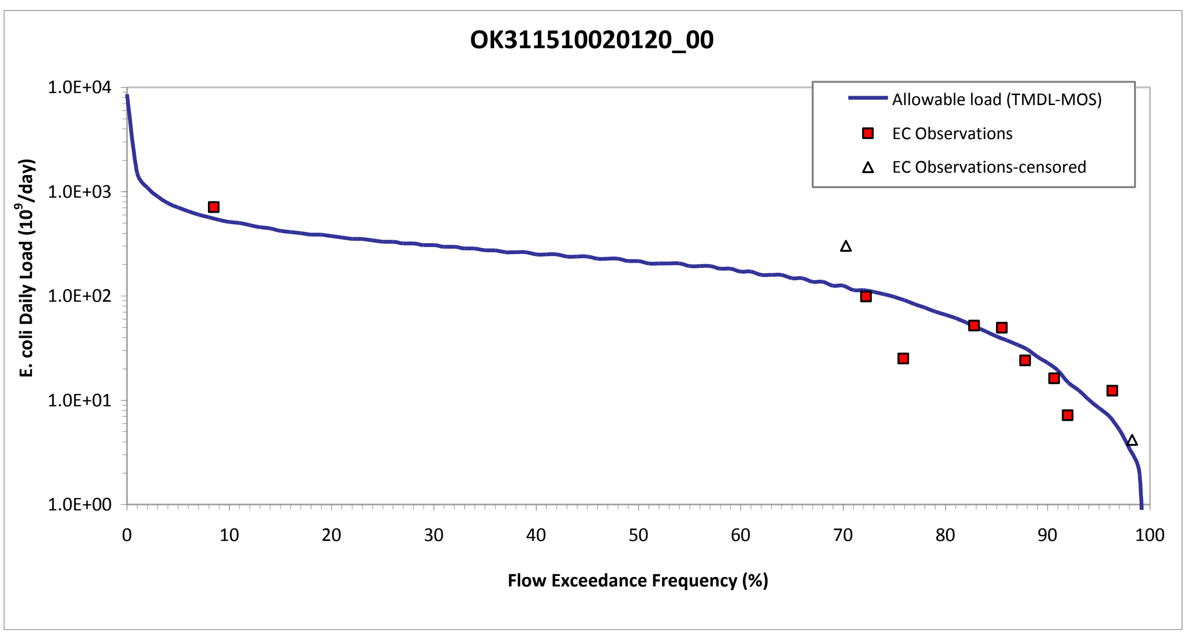
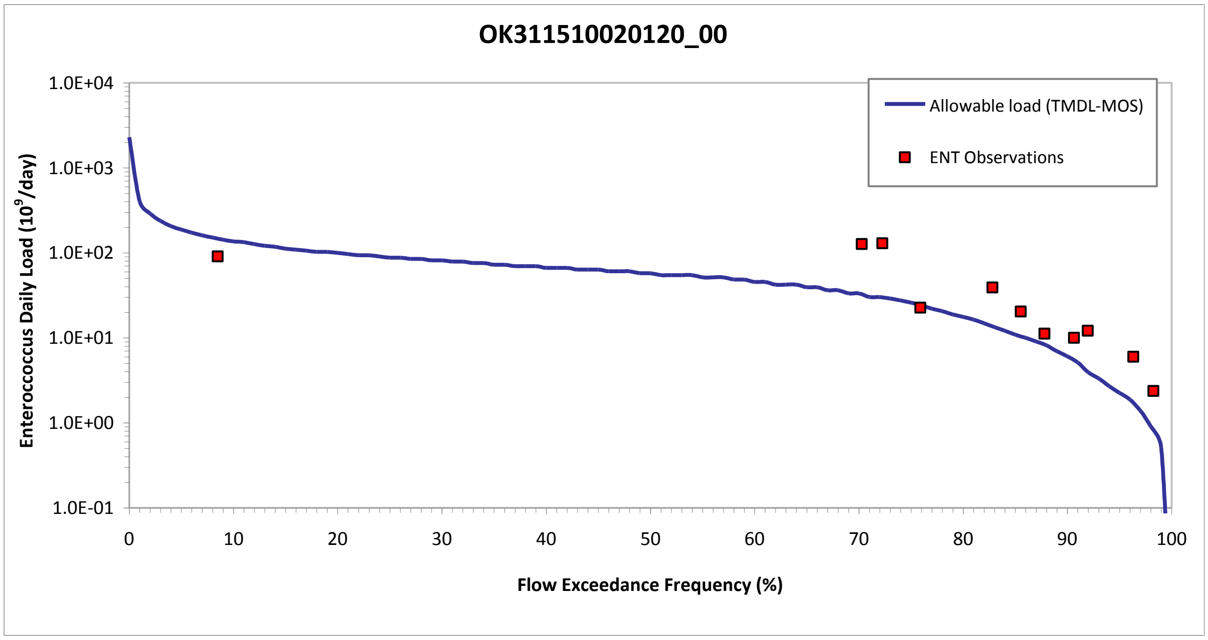
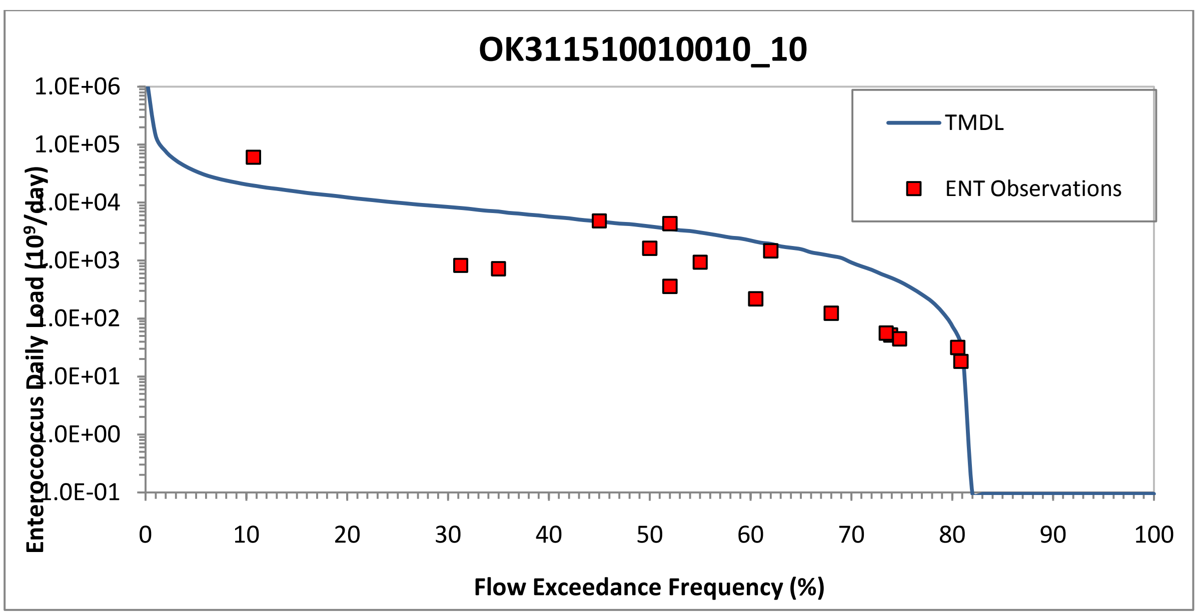


Figure 5-5 Load Duration Curve for Enterococci in Sweetwater Creek (OK311510020120_00)



The LDC for the Red River, North Fork (Figure 5-6) is based on Enterococci measurements during primary contact recreation season at WQM station 311510010010-001AT. The LDC indicates that Enterococci levels occasionally exceed the instantaneous water quality criteria under moderate and high flow conditions, indicative of loading from nonpoint sources.

Figure 5-6 Load Duration Curve for Enterococci in the Red River, North Fork, Carter (OK311510010010_10)



The LDCs for Otter Creek (Figures 5-7 and 5-8) are based on *E. coli* and Enterococci bacteria measurements collected during primary contact recreation season at WQM station OK311500-01-0080F. The LDCs indicate that levels of both bacterial indicators sometimes exceed the instantaneous water quality criteria under all flow conditions.

Figure 5-7 Load Duration Curve for *E. coli* in Otter Creek (OK311500010080_00)

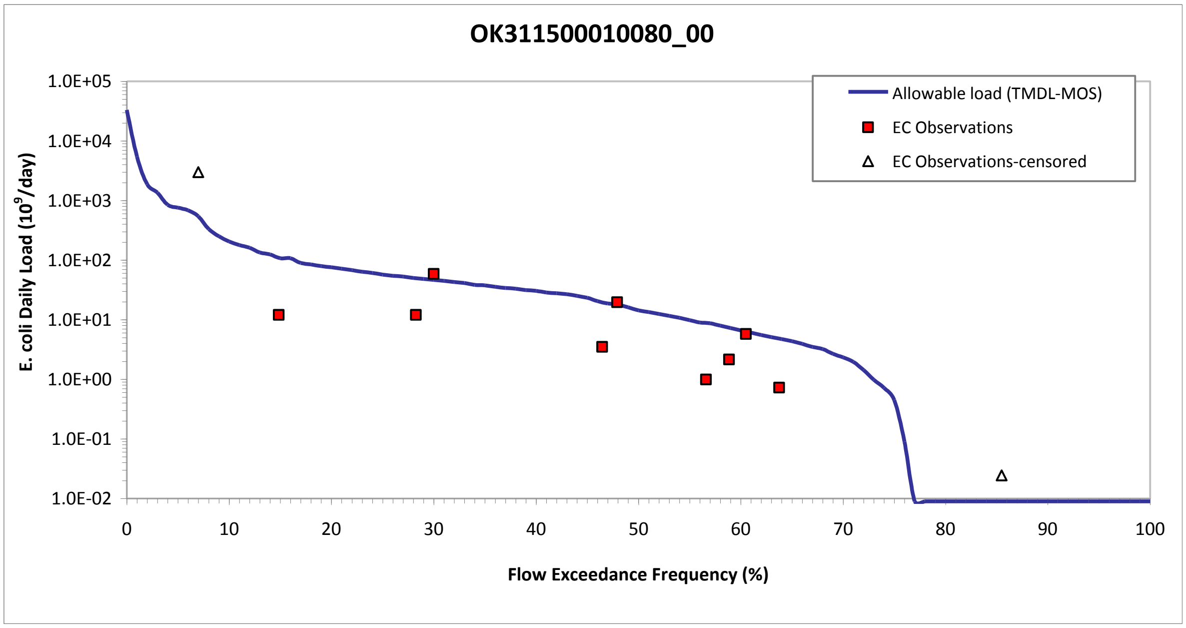
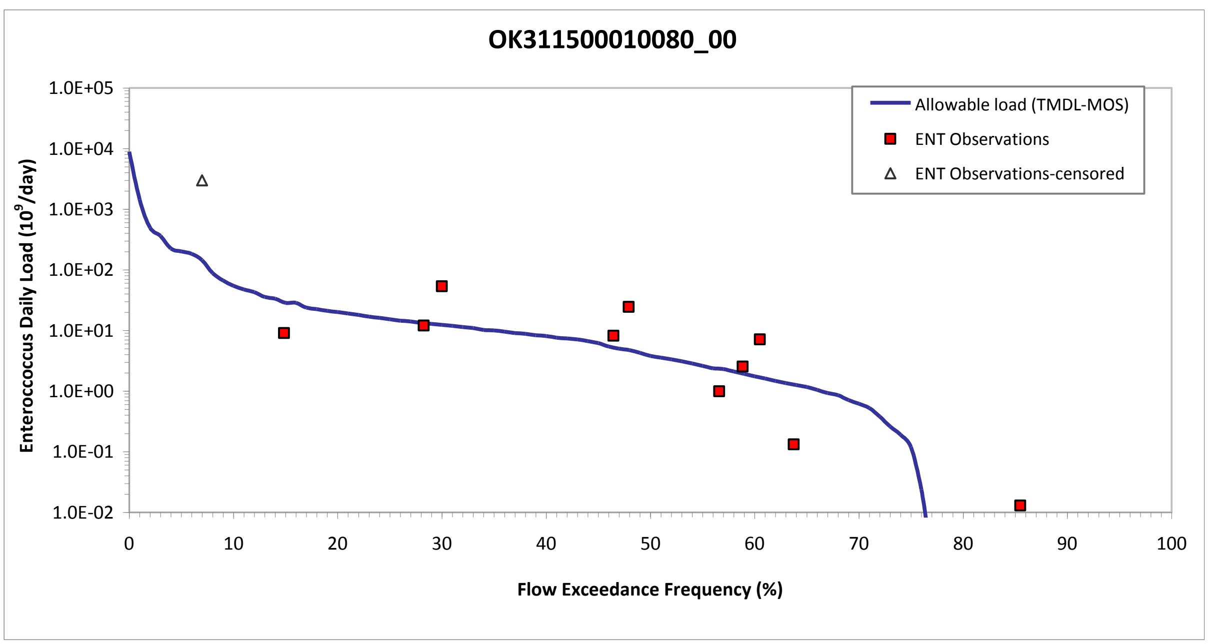


Figure 5-8 Load Duration Curve for Enterococci in Otter Creek (OK311500010080_00)



The LDCs for Deep Red Creek (Figures 5-9 and 5-10) are based on *E. coli* and Enterococci measurements during primary contact recreation season at WQM station 311310-03-0010D. The LDC indicates that *E. coli* levels exceed the instantaneous water quality criteria under moderate and high flow conditions, while Enterococci levels exceed the instantaneous water quality criteria under a wide range of hydrologic conditions, indicative of loading from both point and nonpoint sources.

Figure 5-9 Load Duration Curve for *E. coli* in Deep Red Creek (OK311310030010_00)

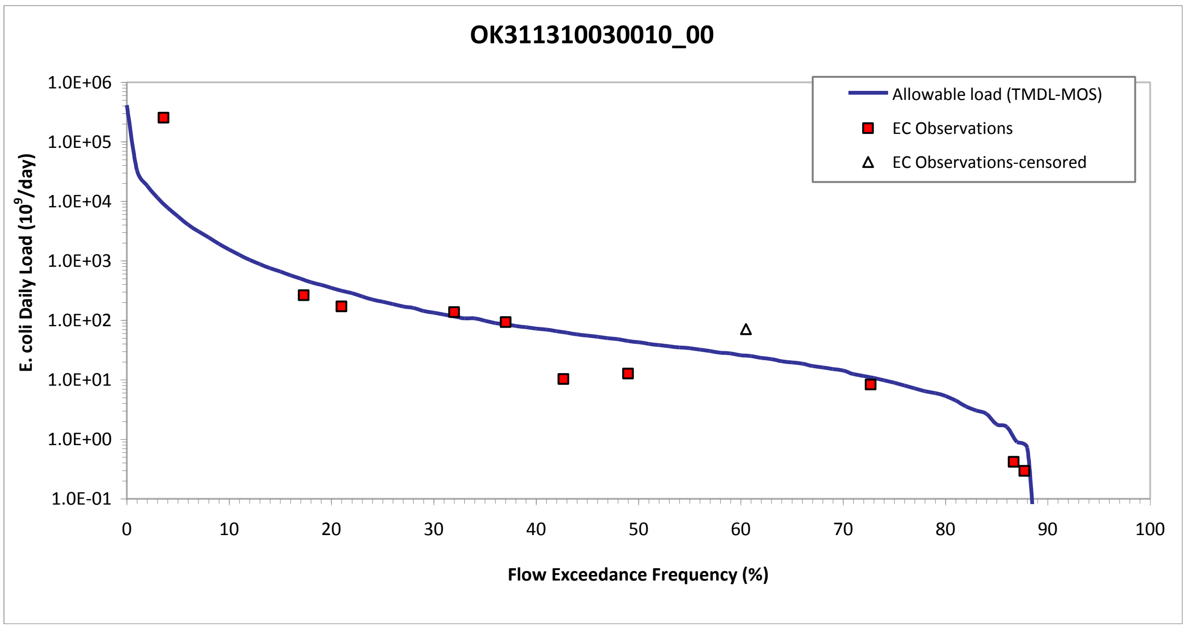
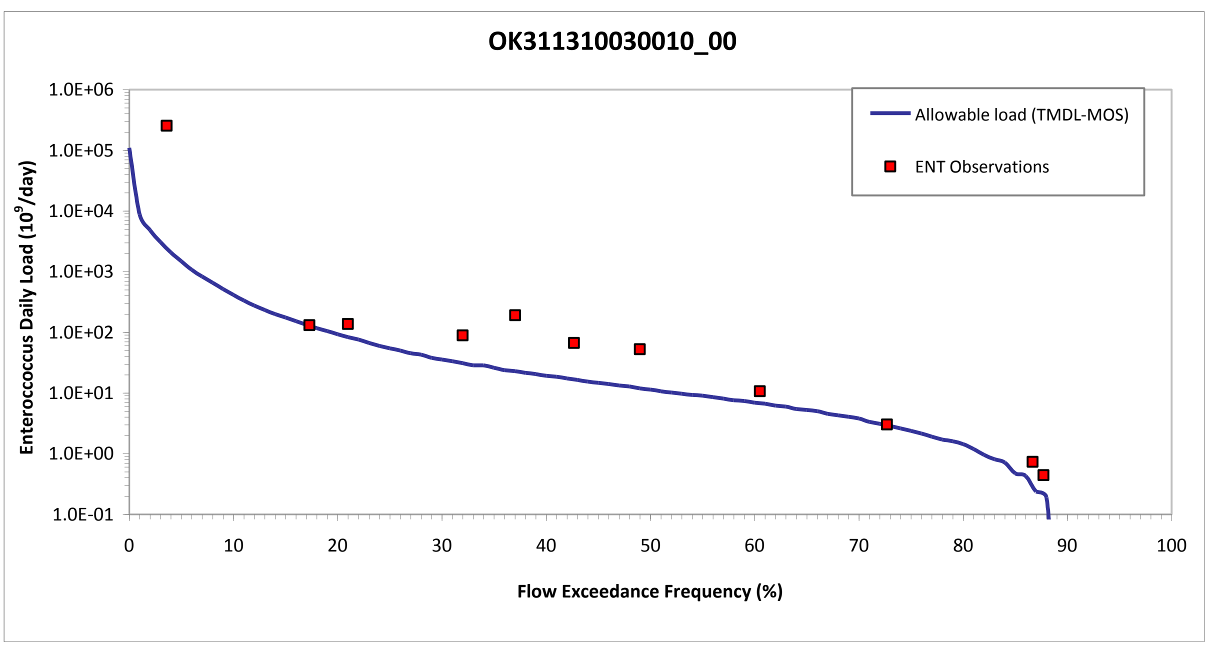
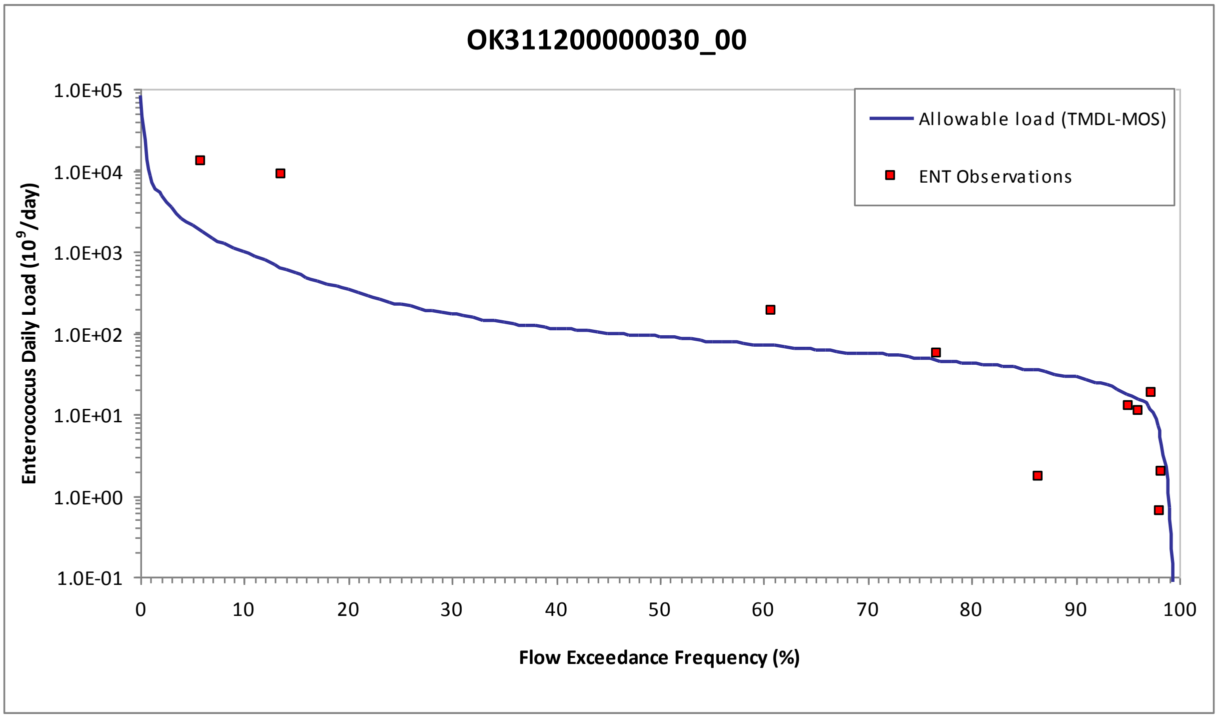


Figure 5-10 Load Duration Curve for Enterococci in Deep Red Creek (OK311310030010_00)



The LDC for Beaver Creek (Figure 5-11) is based on Enterococci measurements during primary contact recreation season at WQM station OK311200-00-0030L. The LDC indicates that Enterococci levels sometimes exceed the instantaneous water quality criteria under all flow conditions.

Figure 5-11 Load Duration Curve for Enterococci in Beaver Creek (OK311200000030_00)



The LDCs for Red Creek are shown in Figures 5-12 and 5-13 for *E. coli* and Enterococci, respectively. They are based on bacteria measurements during primary contact recreation season at WQM station OK31110-01-0290D. The LDCs indicate that *E. coli* and Enterococci levels exceed the instantaneous water quality criteria under moderate and low flow conditions.

Figure 5-12 Load Duration Curve for *E. coli* in Red Creek (OK311100010290_00)

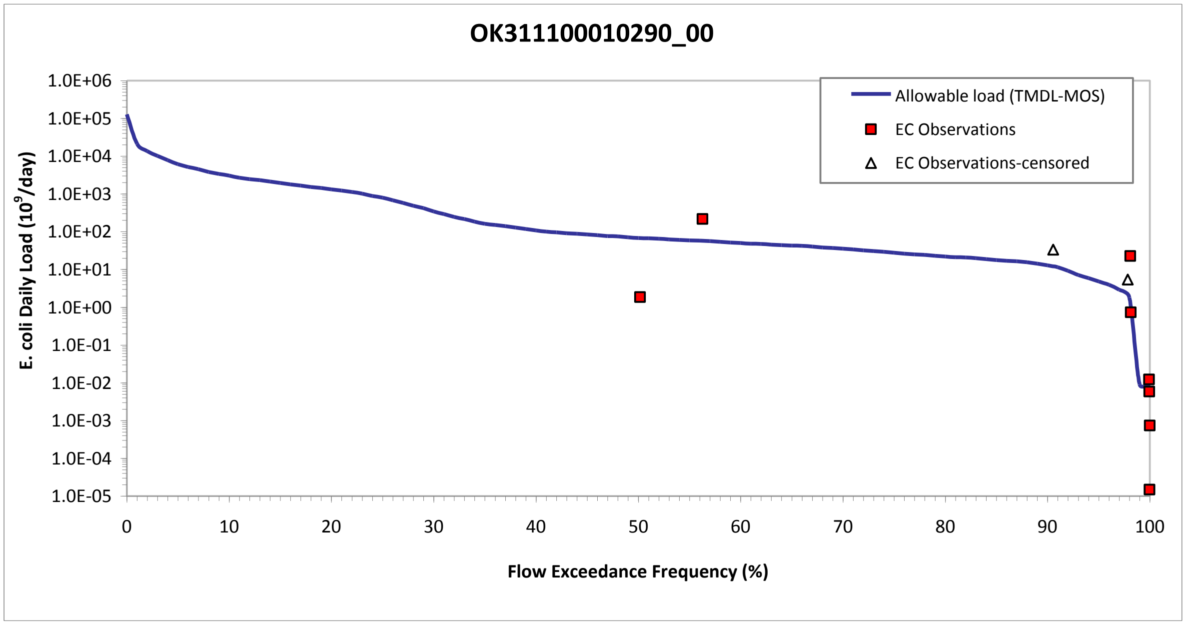
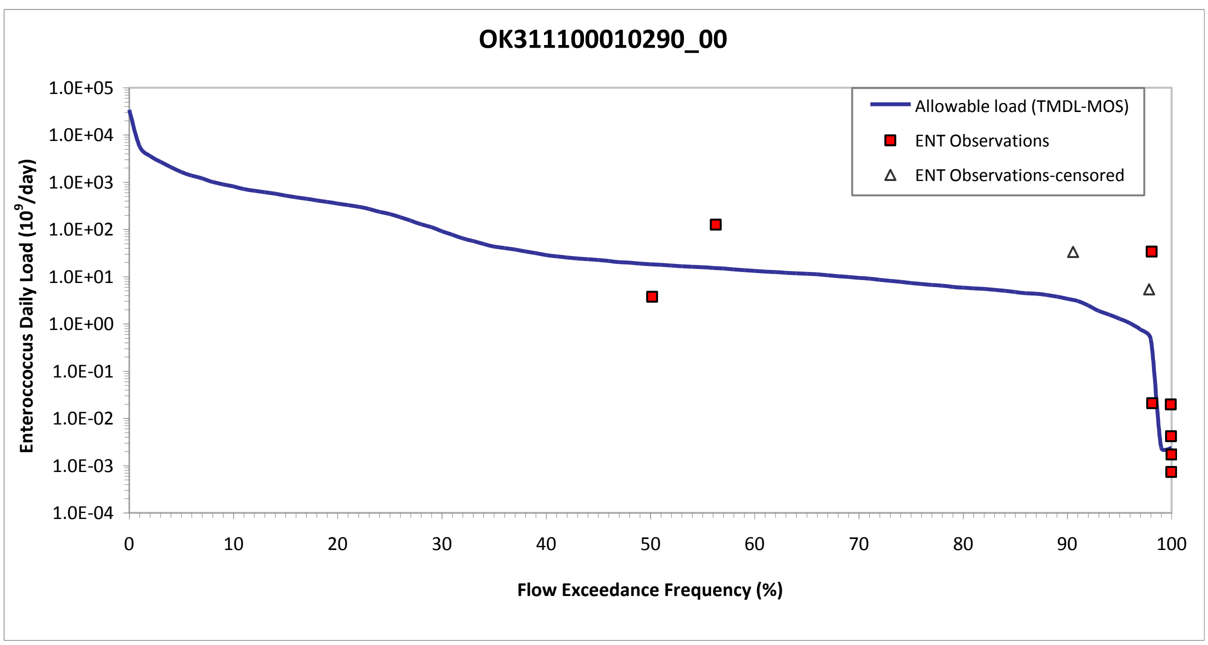


Figure 5-13 Load Duration Curve for Enterococci in Red Creek (OK311100010290_00)



TSS LDC: To calculate the TSS load at the WQ target, the flow rate at each flow exceedance percentile is multiplied by a unit conversion factor (*5.39377 L*s*lb /ft^3/day/mg*) and the TSS goal for each waterbody. This calculation produces the maximum TSS load in the waterbody that will result in attainment of the 50 NTU target for turbidity. The allowable TSS loads at the WQS establish the TMDL and are plotted versus flow exceedance percentile as a LDC. The x-axis indicates the flow exceedance percentile, while the y-axis is expressed in terms of a TSS load in pounds per day.

To estimate existing loading, TSS and turbidity observations from 1998 to 2009 are paired with the flows measured or projected on the same date for the waterbody. For sampling events with both TSS and turbidity data, the measured TSS value is used. Pollutant loads are then calculated by multiplying the TSS concentration by the flow rate and the unit conversion factor. The associated flow exceedance percentile is then matched with the flow from the tables provided in Appendix B. The observed TSS or converted turbidity loads are then added to the LDC plot as points. These points represent individual ambient water quality samples of TSS. Points above the LDC indicate the TSS goal was exceeded at the time of sampling. Conversely, points under the LDC indicate the sample did not exceed the TSS goal.

Figures 5-14 through Figure 5-37 show the TSS LDCs developed for the twenty-four waterbodies addressed in this TMDL report. Data in the figures indicate that for most waterbodies, TSS levels exceed the water quality target during all flow conditions, indicating water quality impairments due to nonpoint sources or a combination of point and nonpoint sources. Wet weather influenced samples found during low flow conditions can be caused by an isolated rainfall event during dry weather conditions. It is noted that the LDC plots include data under all flow conditions to show the overall condition of the waterbody. However, the turbidity standard only applies for base-flow conditions. Thus, when interpreting the LDC to derive TMDLs for TSS, only the portion of the graph corresponding to flows above the 25th flow exceedance percentile should be used. WLAs for point sources discharges (continuous) of inorganic TSS are shown on a LDC as a horizontal line which represents the sum of all WLAs for TSS in a given watershed.

Figure 5-14 Load Duration Curve for Total Suspended Solids in Deer Creek (OK311800000070_00)

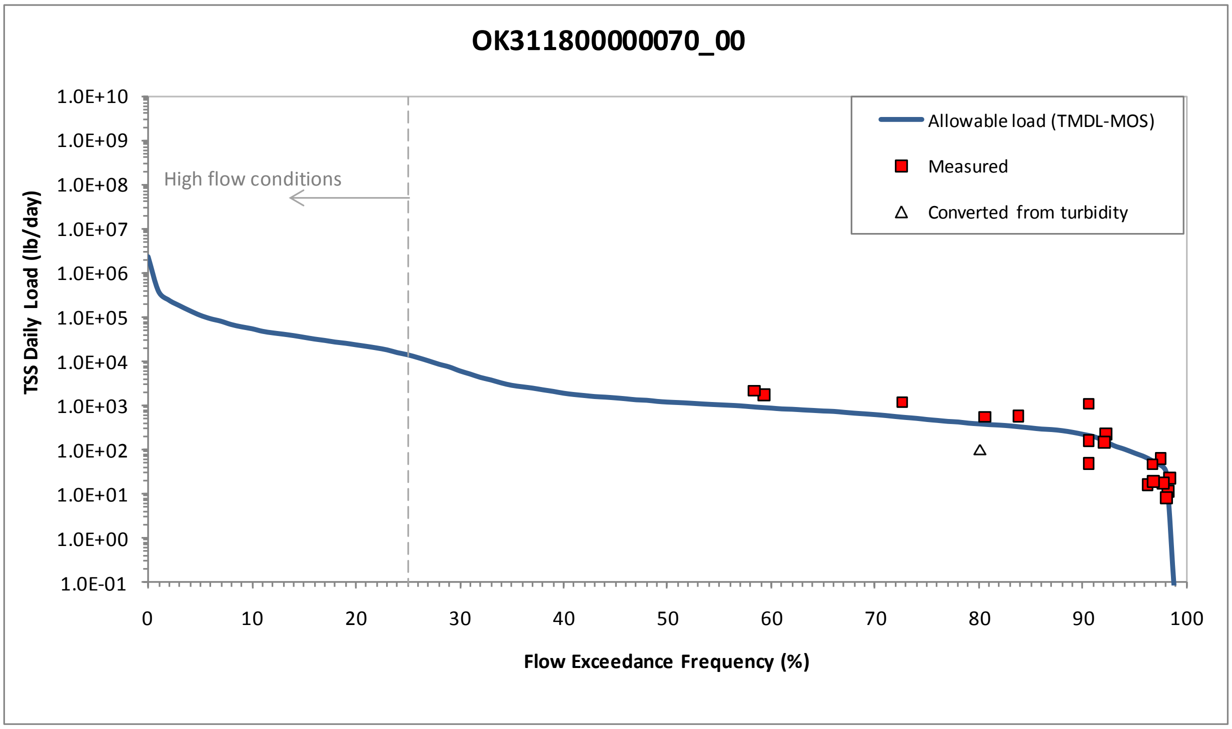


Figure 5-15 Load Duration Curve for Total Suspended Solids in Haystack Creek (OK311800000040_00)

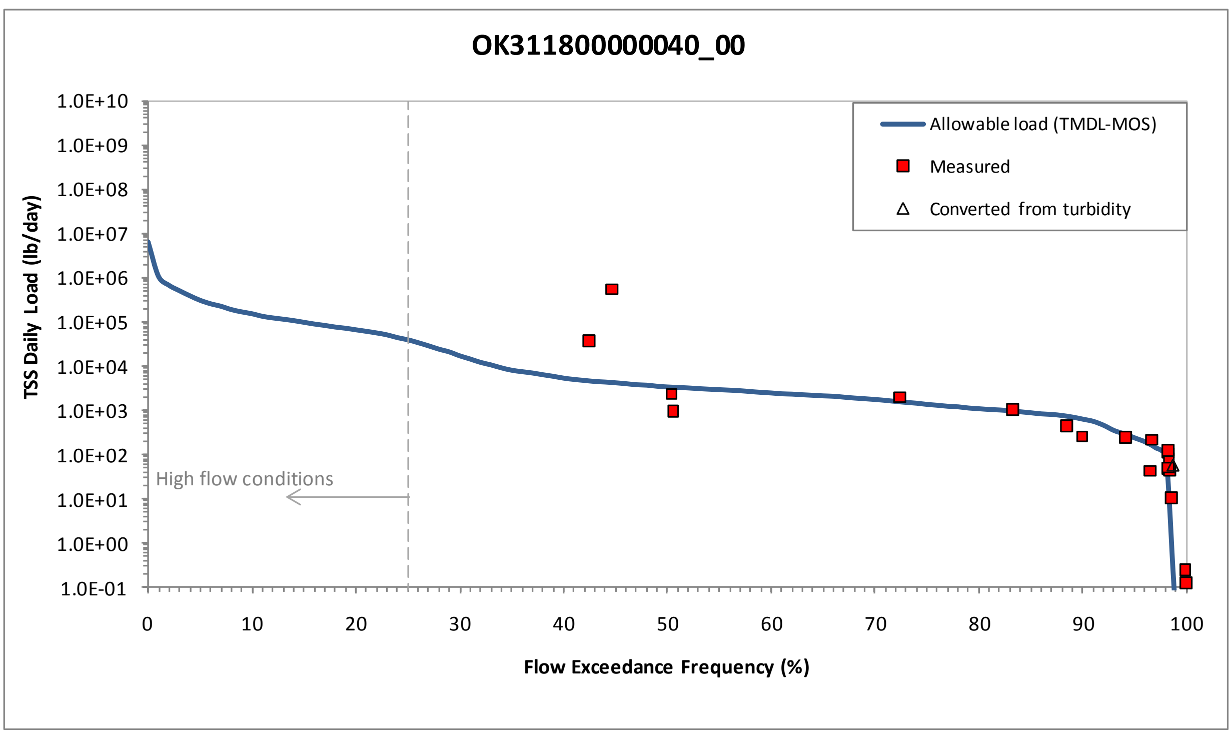


Figure 5-16 Load Duration Curve for Total Suspended Solids in Sandy Creek (Lebos) (OK311600010040_00)

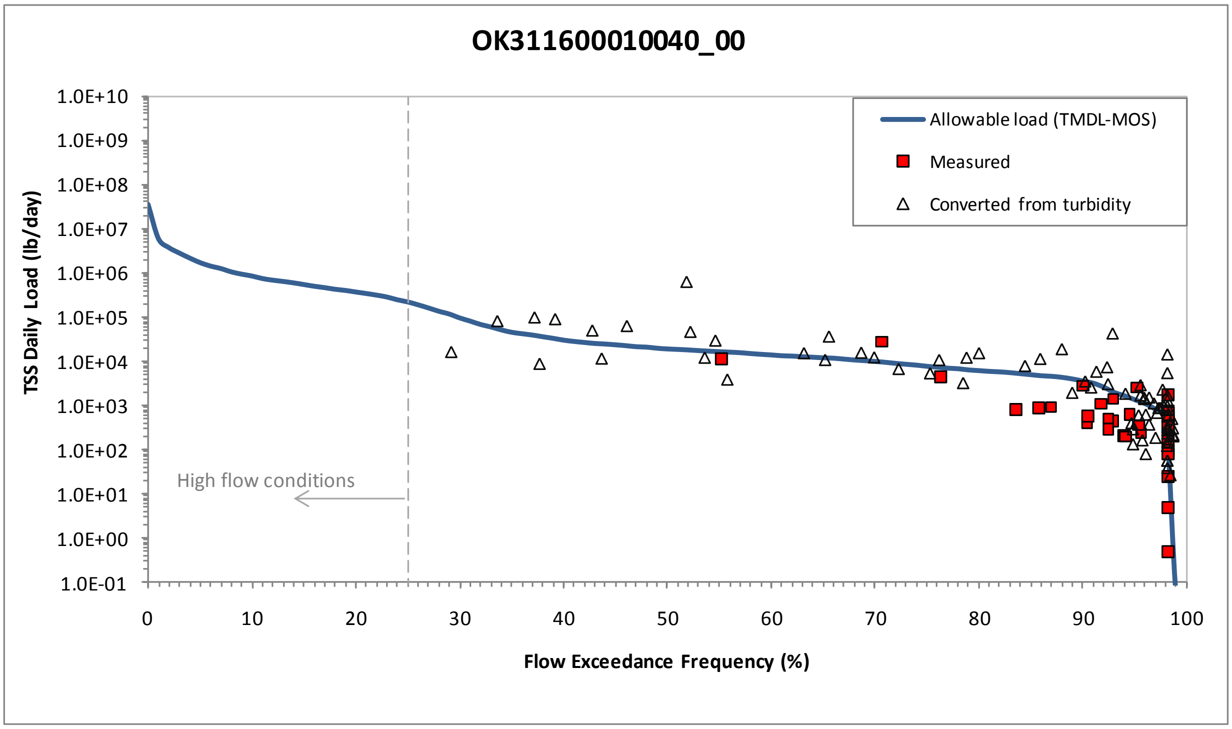


Figure 5-17 Load Duration Curve for Total Suspended Solids in Gypsum Creek (OK311600010020_00)

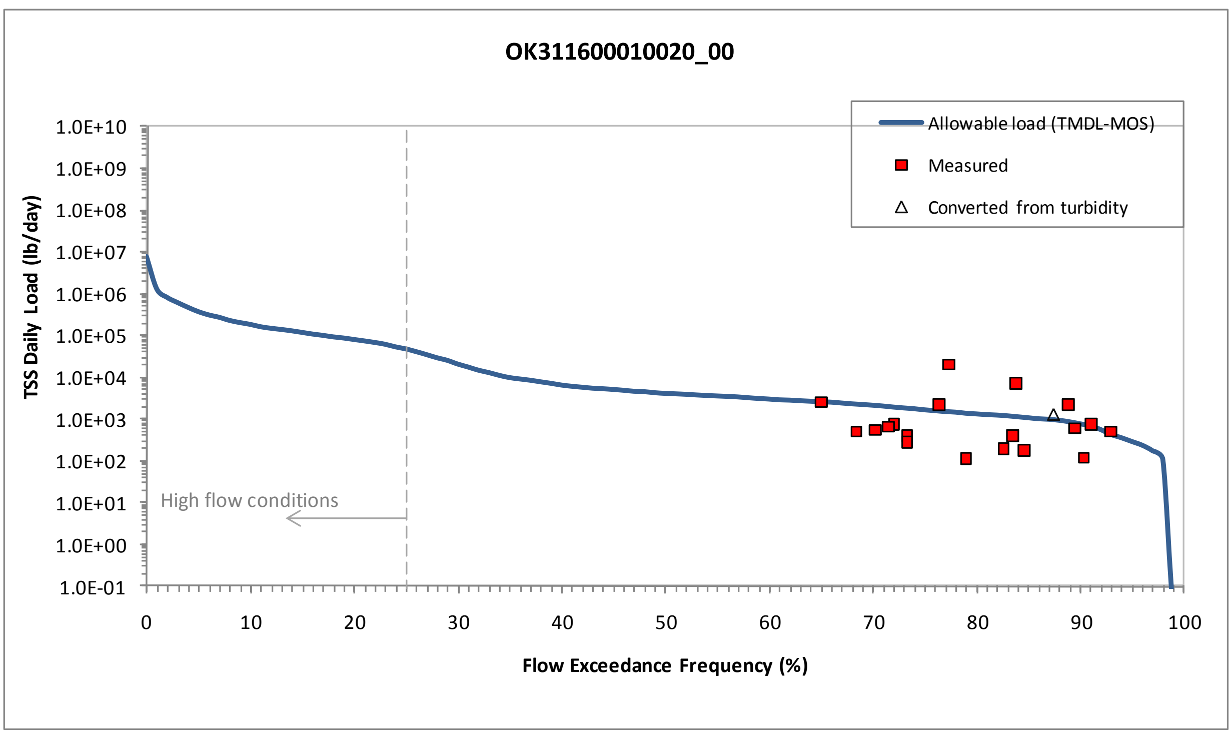


Figure 5-18 Load Duration Curve for Total Suspended Solids in Sweetwater Creek (OK311510020120_00)

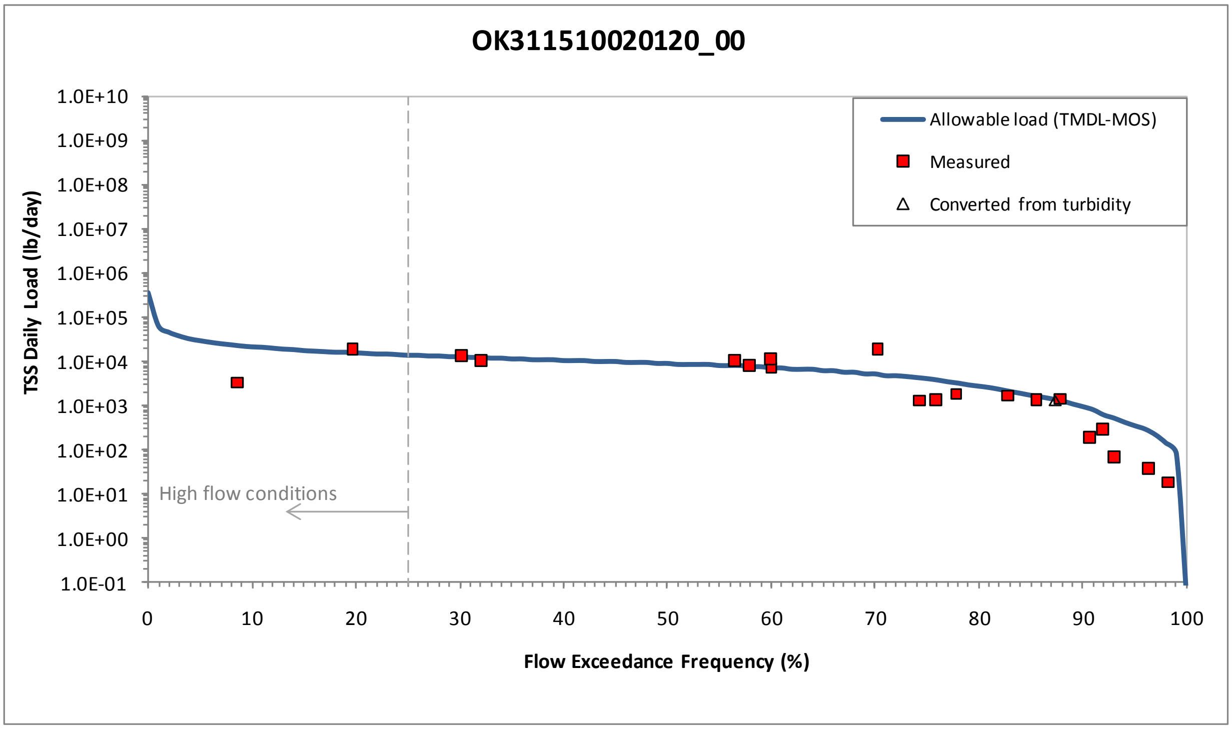


Figure 5-19 Load Duration Curve for Total Suspended Solids in Red River, North Fork, Carter (OK311510010010_10)

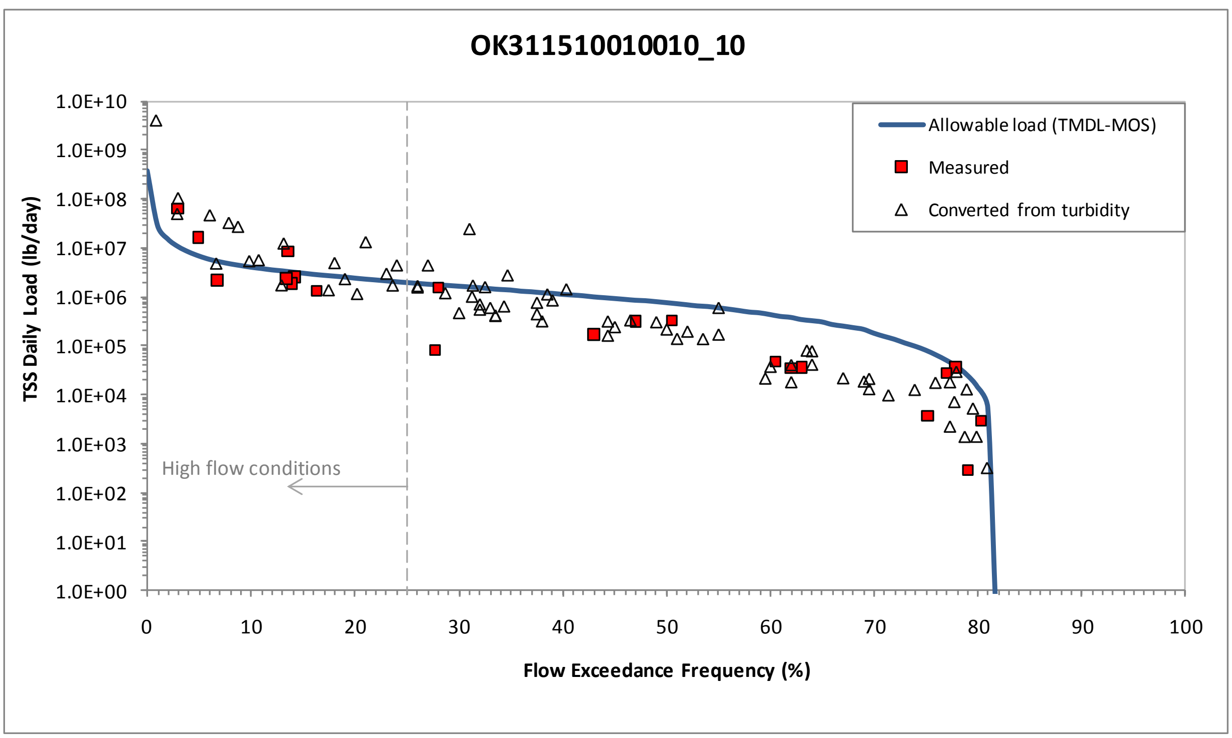


Figure 5-20 Load Duration Curve for Total Suspended Solids in Elk Creek (OK311500030010_00)

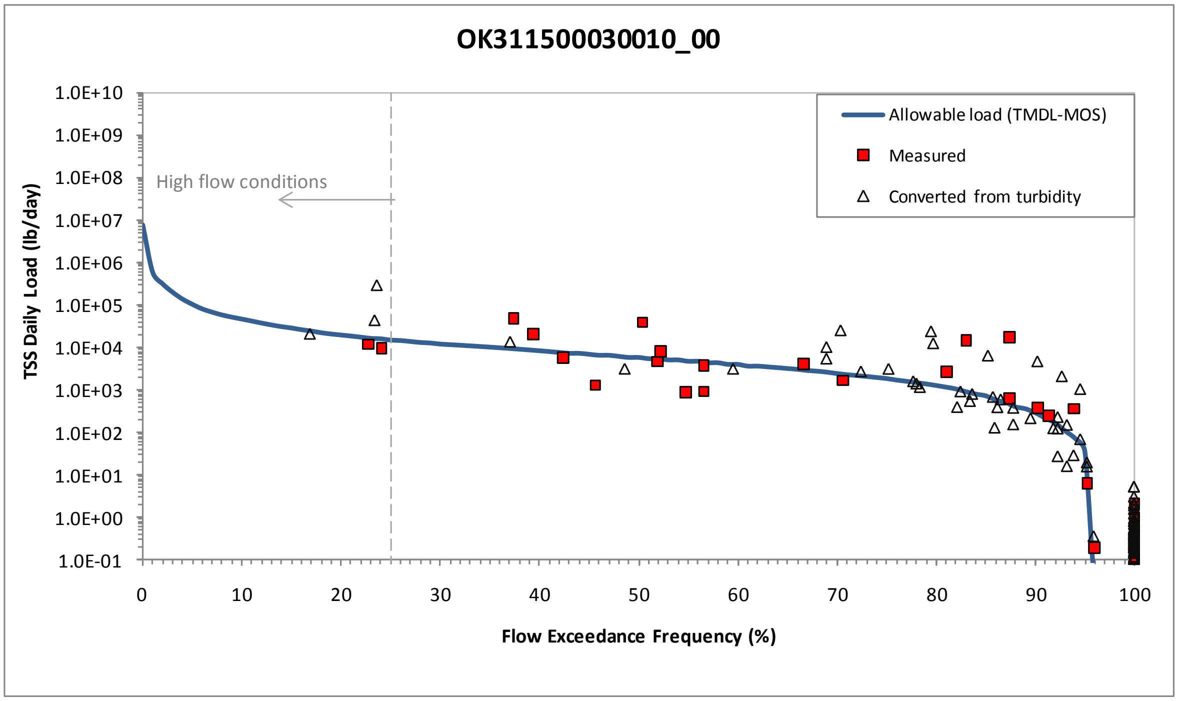
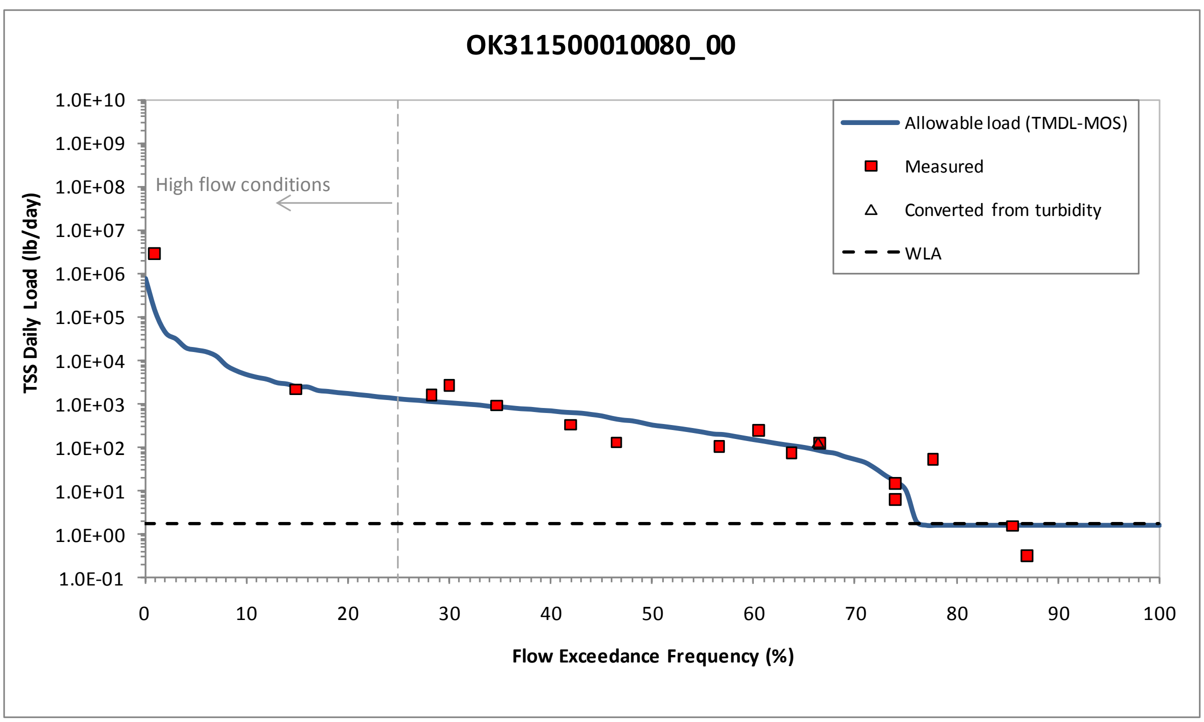


Figure 5-21 Load Duration Curve for Total Suspended Solids in Otter Creek (OK311500010080_00)



Note: The last part of the curve (above the 75th percentile), where loads at the WQ target appear to be slightly lower than the WWTP wasteload allocation, is assumed to be equal to the WLA. This explains the difference of shape between the LDC and FDC at very low flows.

Figure 5-22 Load Duration Curve for Total Suspended Solids in Stinking Creek (OK311500010050_00)

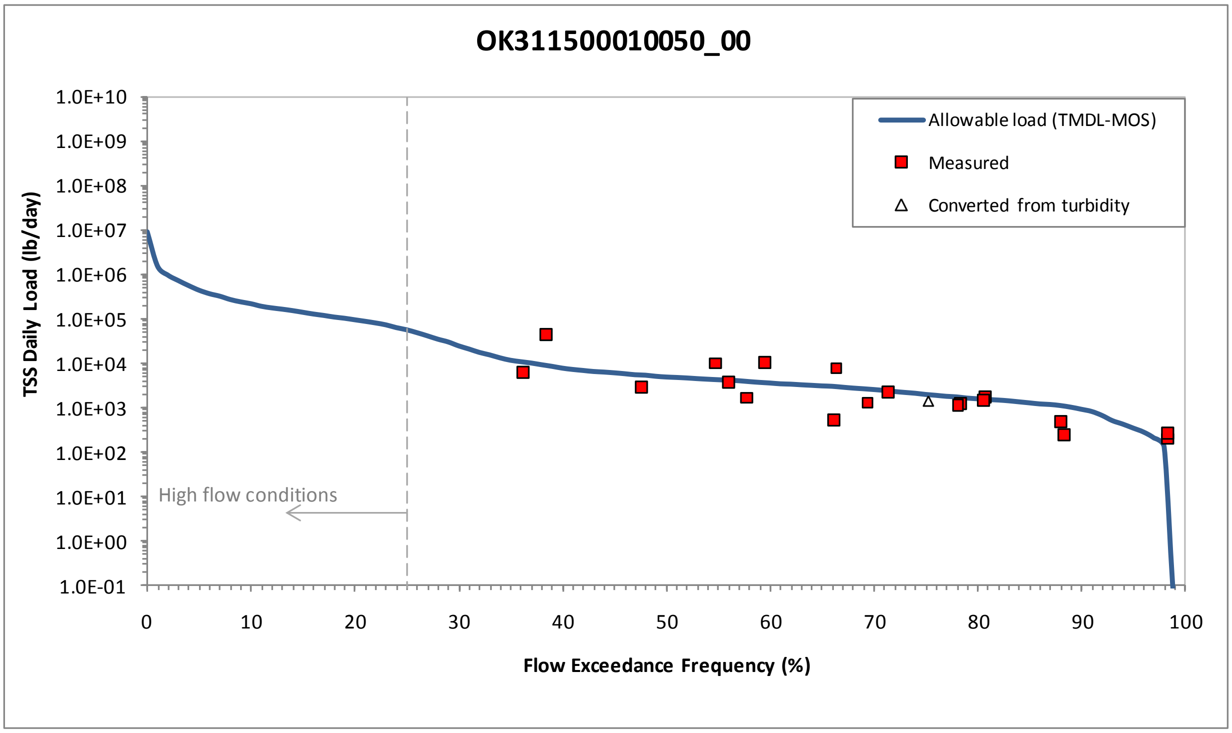


Figure 5-23 Load Duration Curve for Total Suspended Solids in the Red River, North Fork, Headrick (OK311500010020_10)

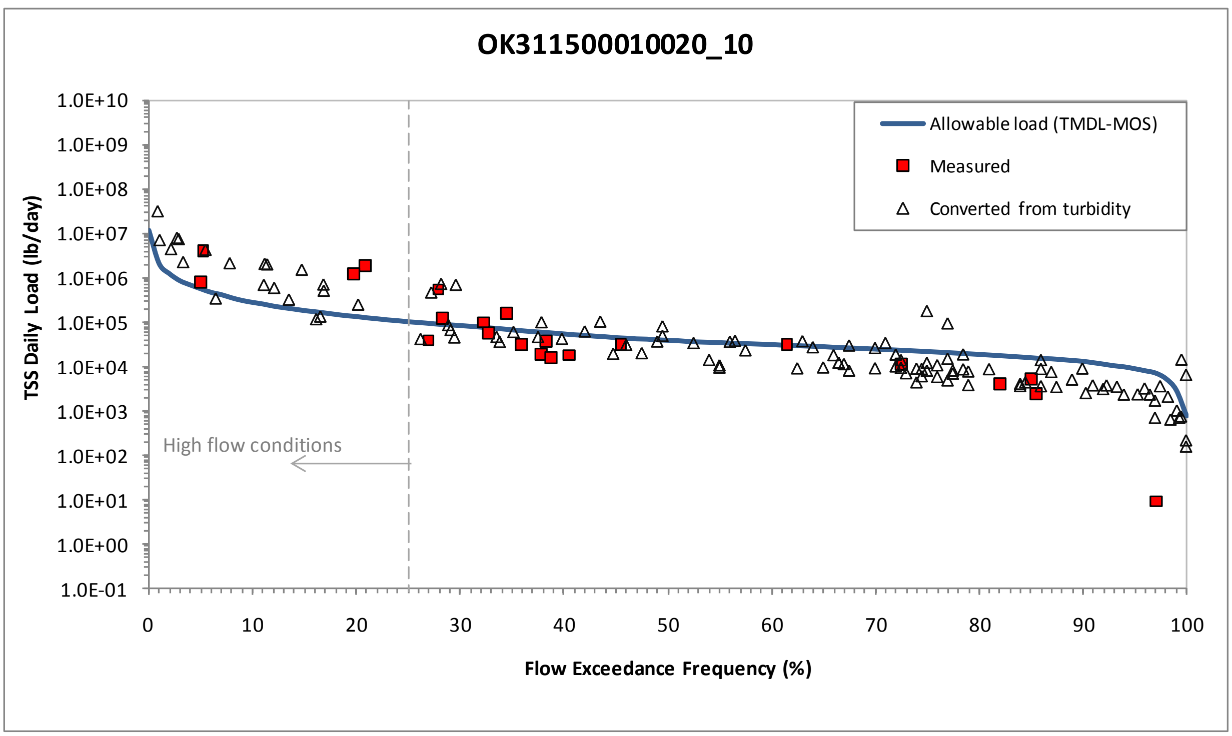


Figure 5-24 Load Duration Curve for Total Suspended Solids in Brush Creek (OK311310030050_00)

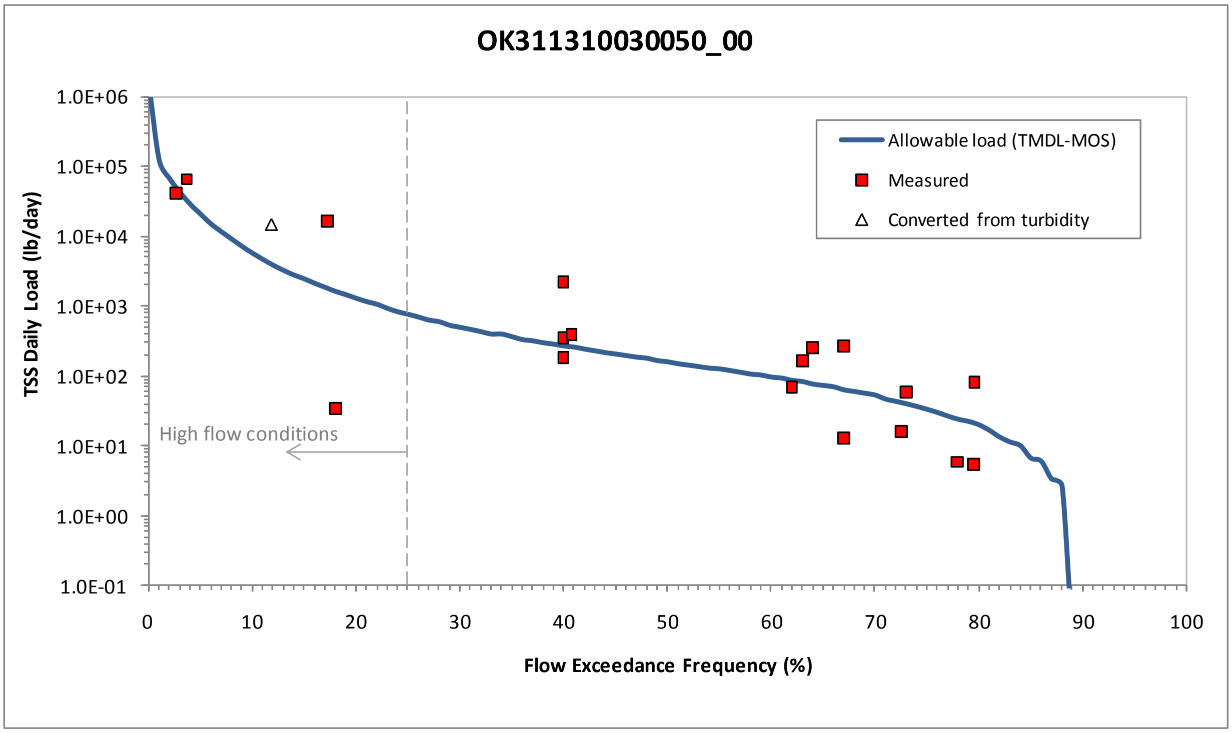


Figure 5-25 Load Duration Curve for Total Suspended Solids in Little Deep Red Creek (OK311310030040_00)

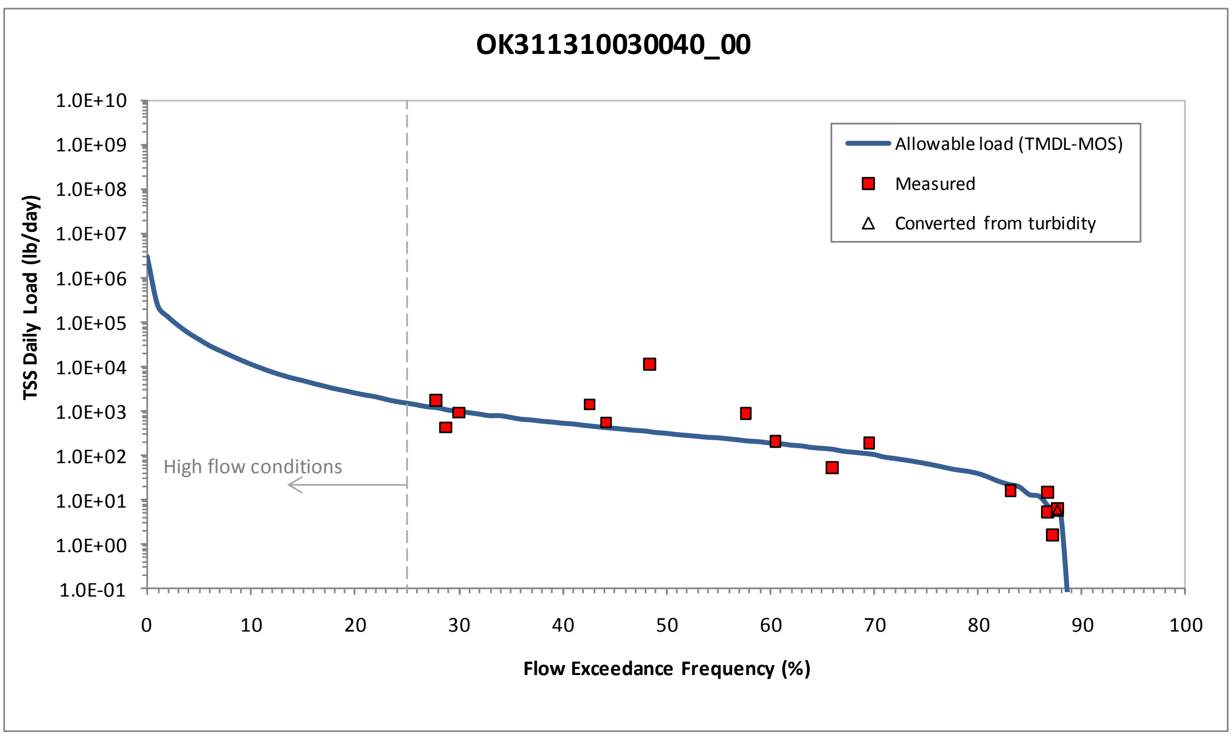


Figure 5-26 Load Duration Curve for Total Suspended Solids in Deep Red Creek (OK311310030010_00)

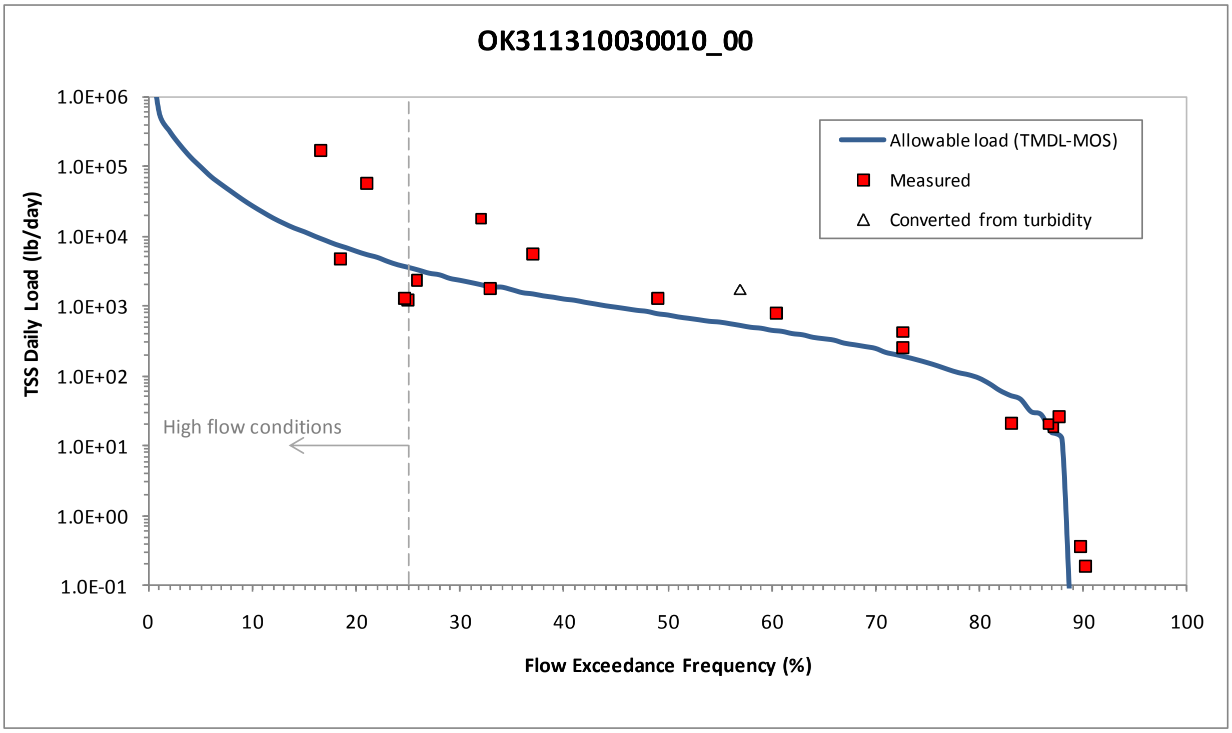


Figure 5-27 Load Duration Curve for Total Suspended Solids in West Cache Creek (OK311310020010_00)

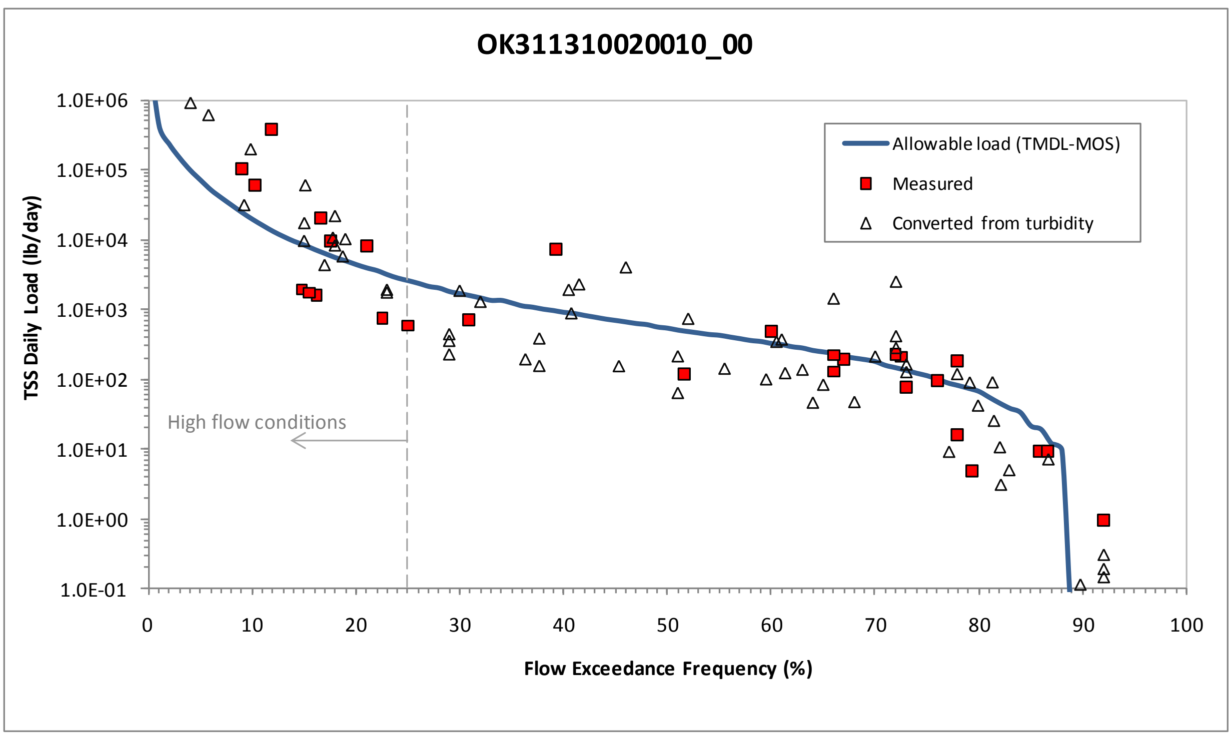


Figure 5-28 Load Duration Curve for Total Suspended Solids in Suttle Creek (OK311310010070_00)

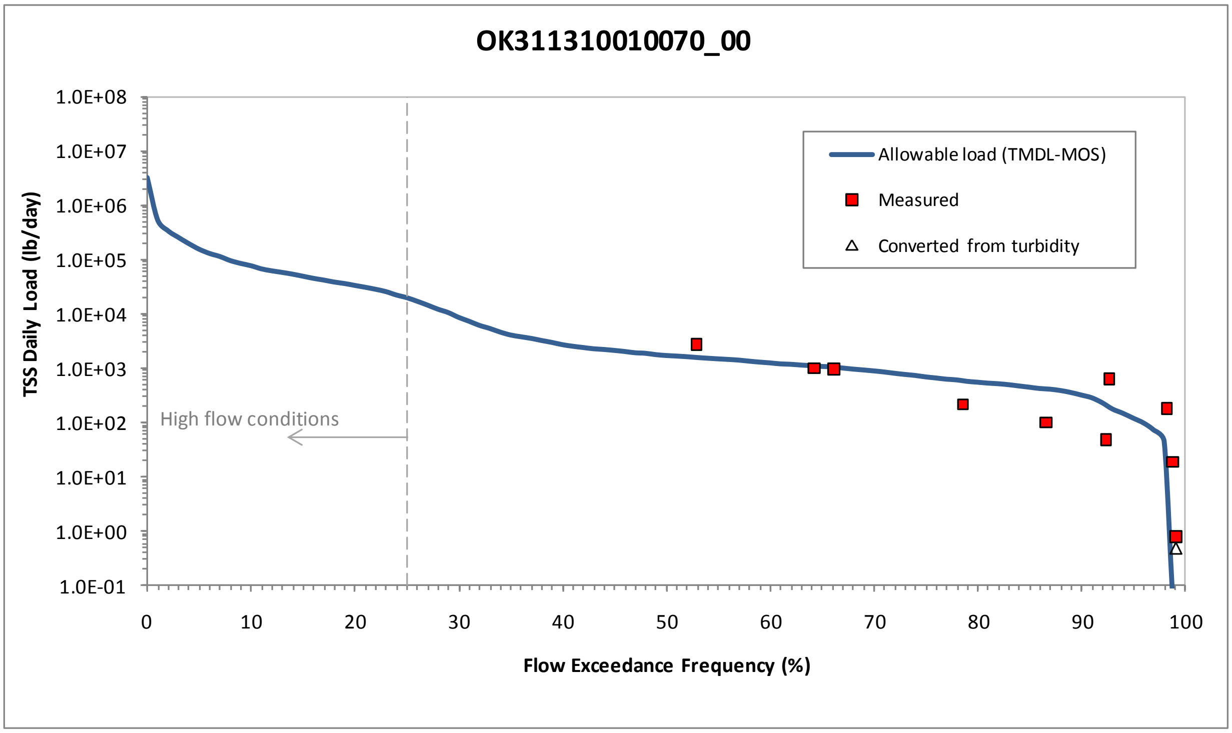


Figure 5-29 Load Duration Curve for Total Suspended Solids in East Cache Creek, Walters (OK311300010020_10)

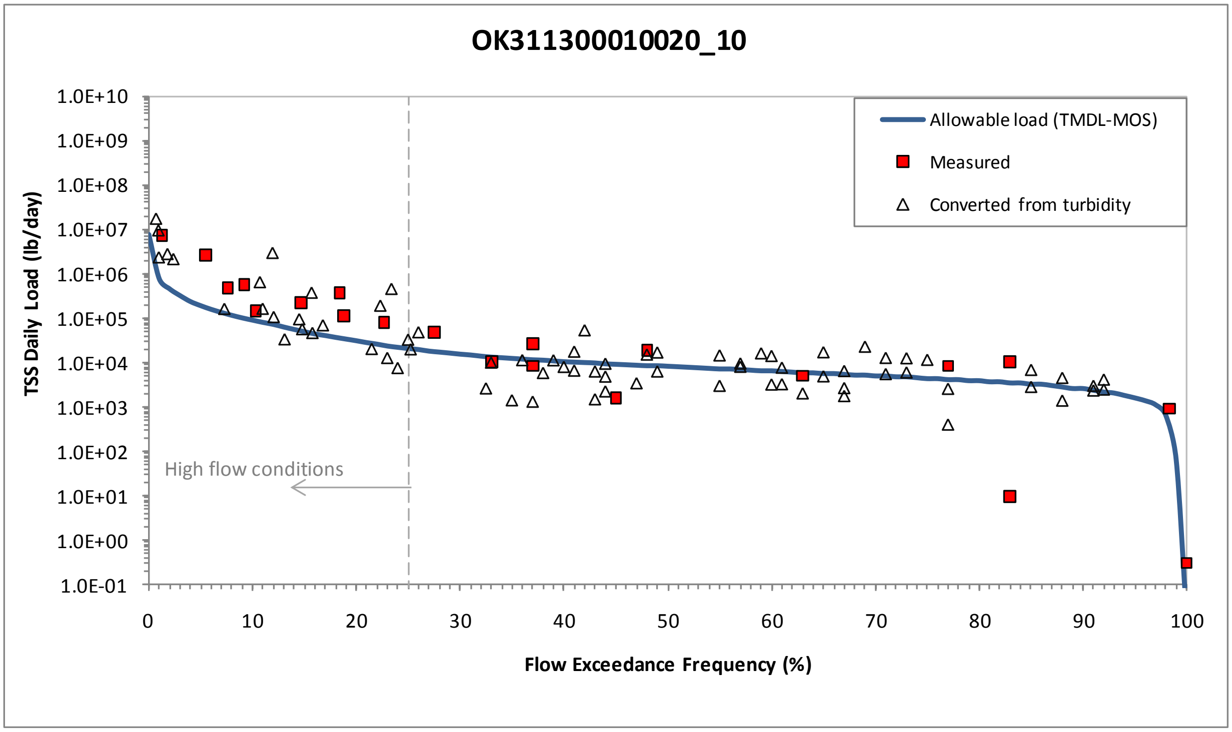


Figure 5-30 Load Duration Curve for Total Suspended Solids in East Cache Creek (OK311300010020_00)

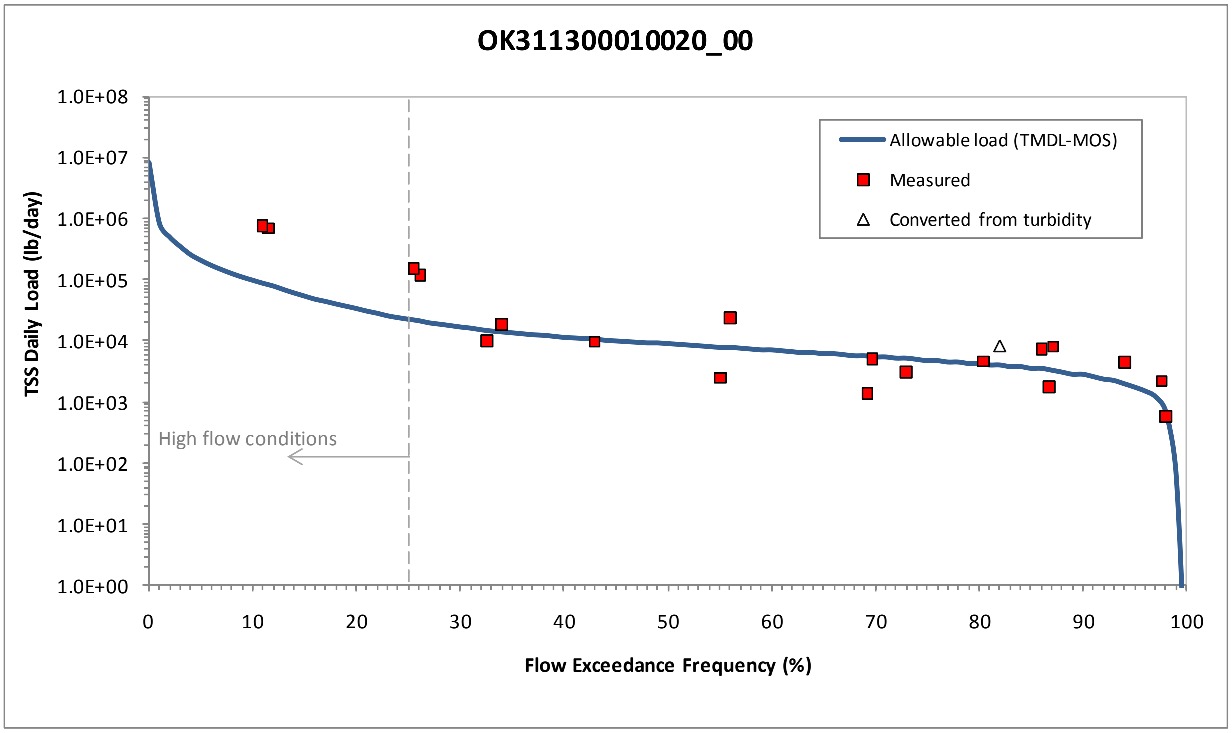


Figure 5-31 Load Duration Curve for Total Suspended Solids in Dry Creek (OK311200000080_00)

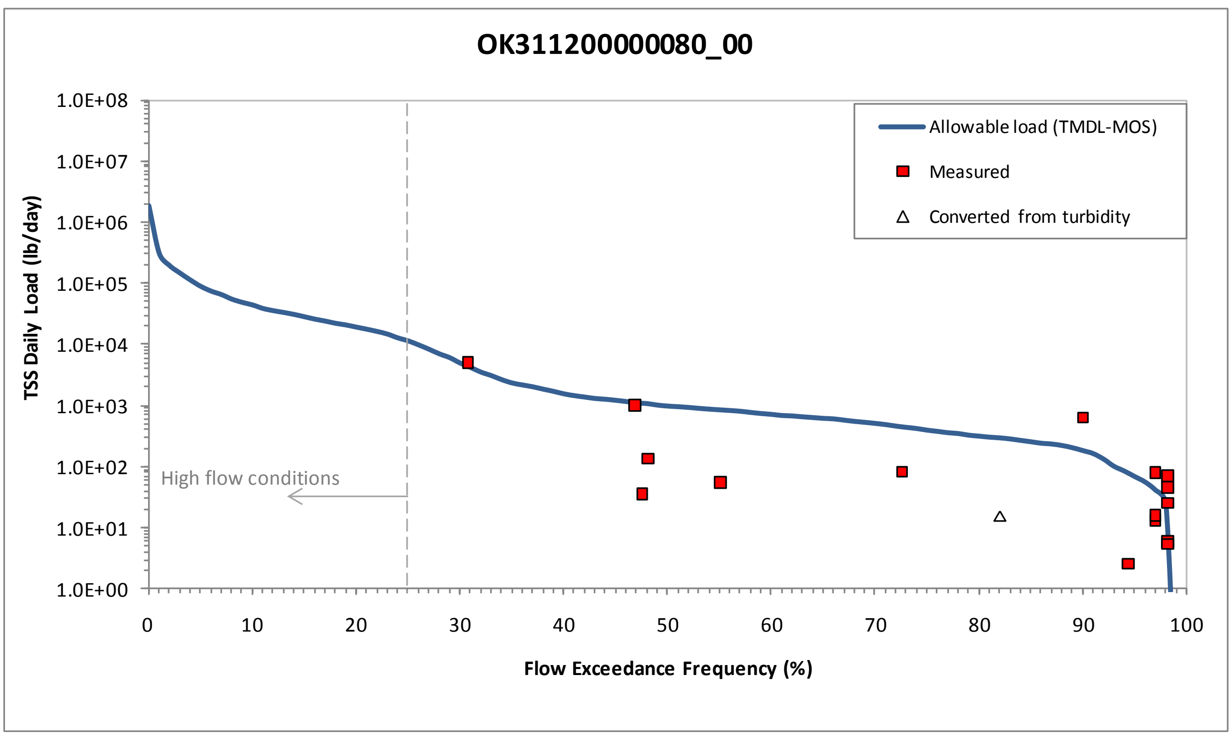


Figure 5-32 Load Duration Curve for Total Suspended Solids in Cow Creek (OK311200000060_00)

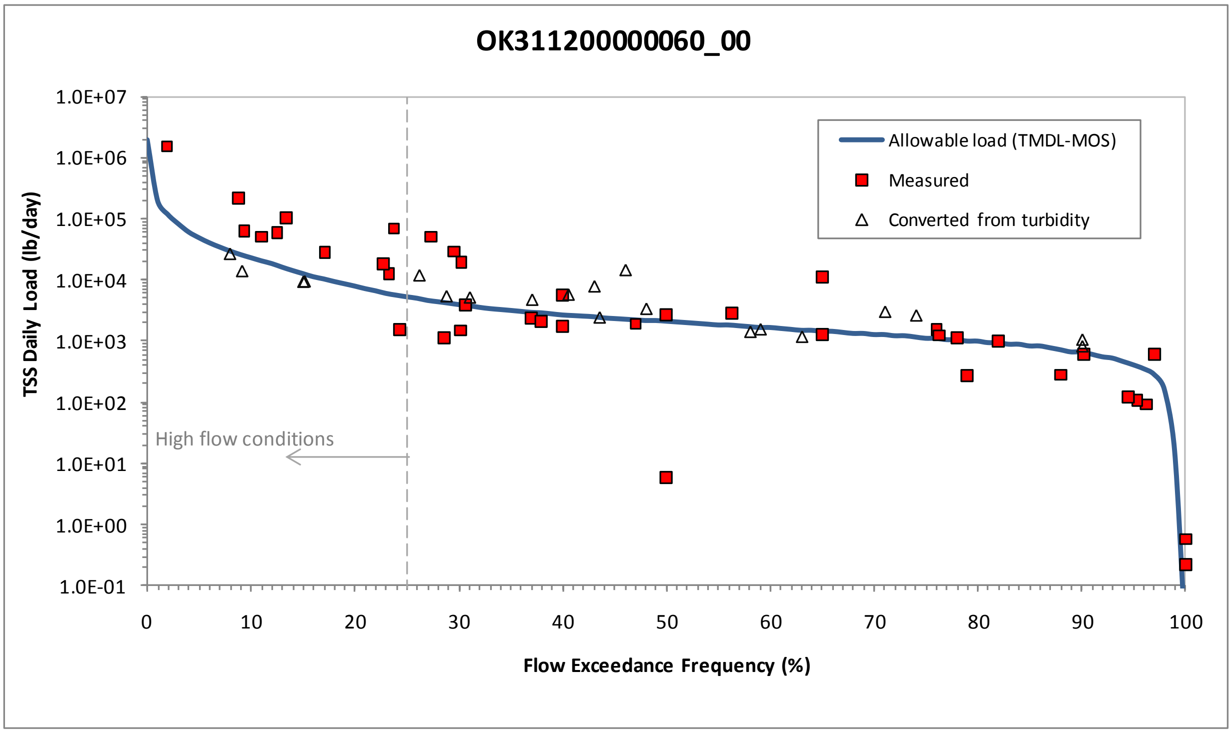


Figure 5-33 Load Duration Curve for Total Suspended Solids in Beaver Creek (OK3112000000030_00)

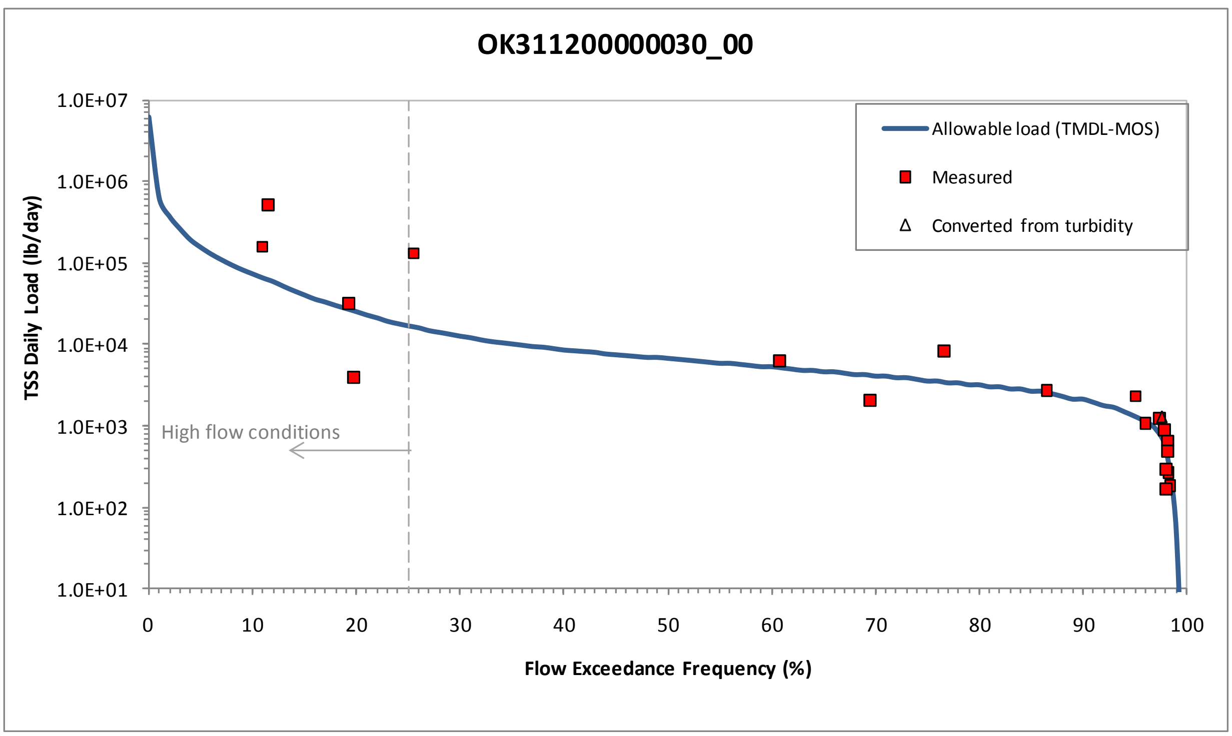


Figure 5-34 Load Duration Curve for Total Suspended Solids in Lower West Mud Creek (OK311100040080_00)

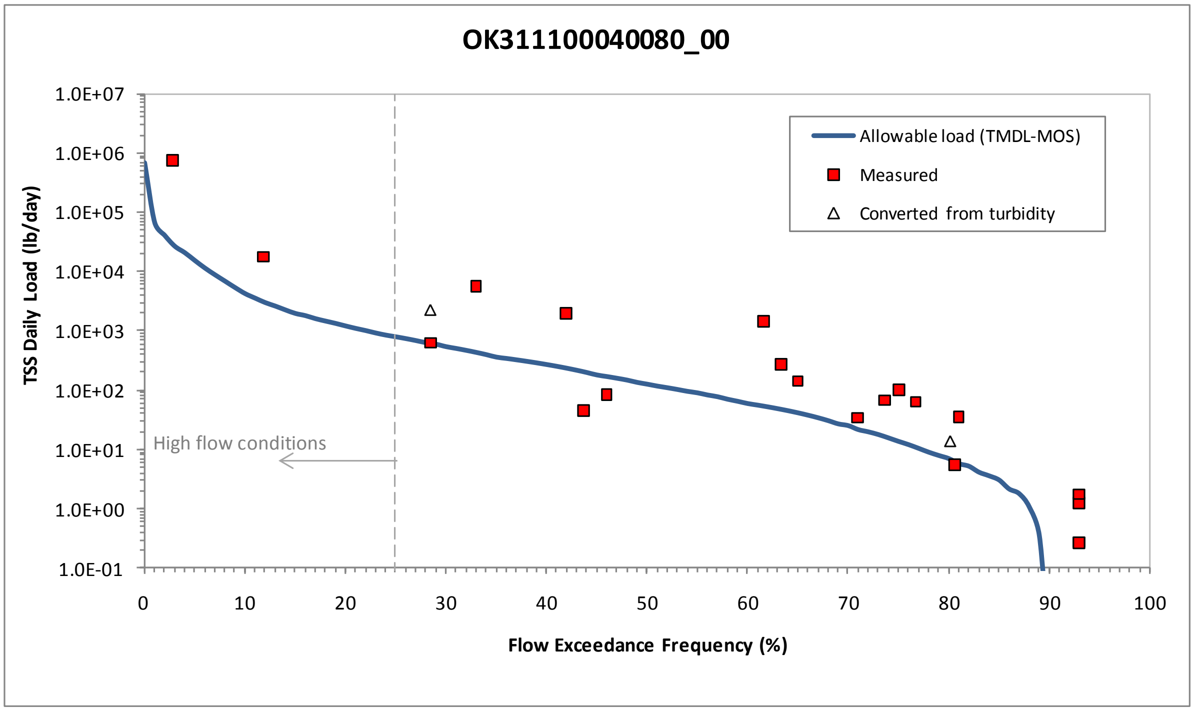


Figure 5-35 Load Duration Curve for Total Suspended Solids in Mud Creek (OK311100040010_00)

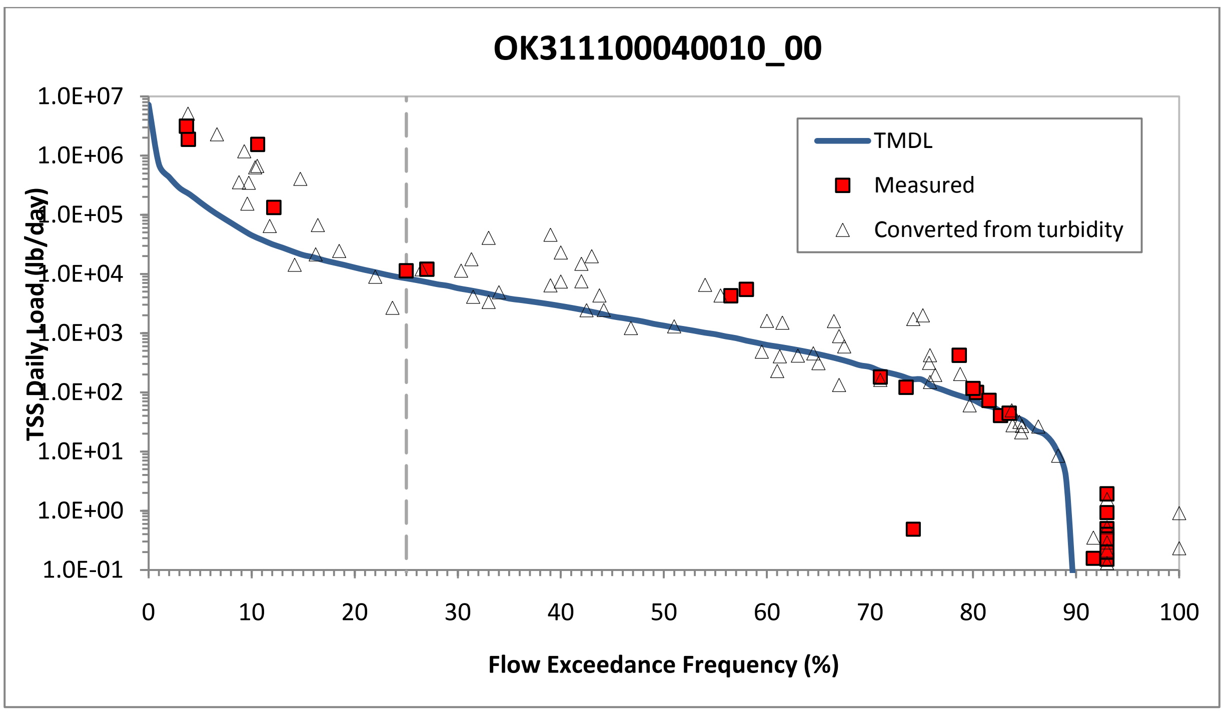


Figure 5-36 Load Duration Curve for Total Suspended Solids in Fleetwood Creek (OK311100010300_00)

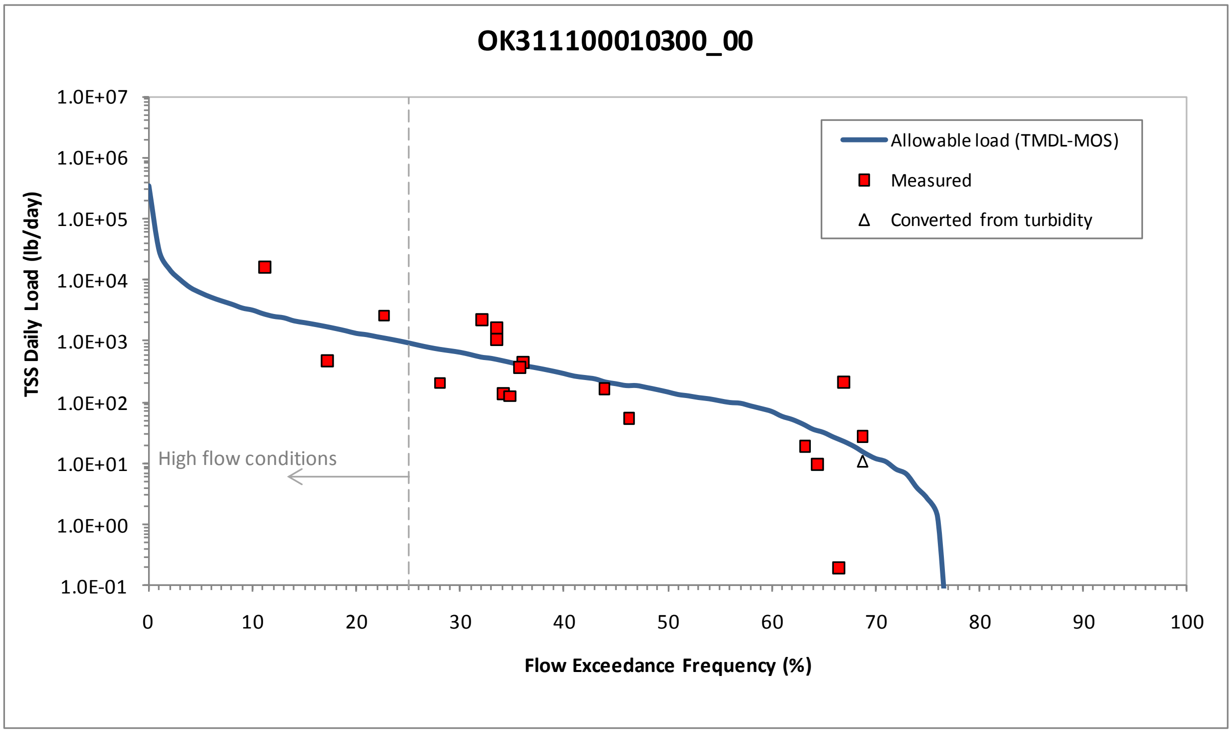
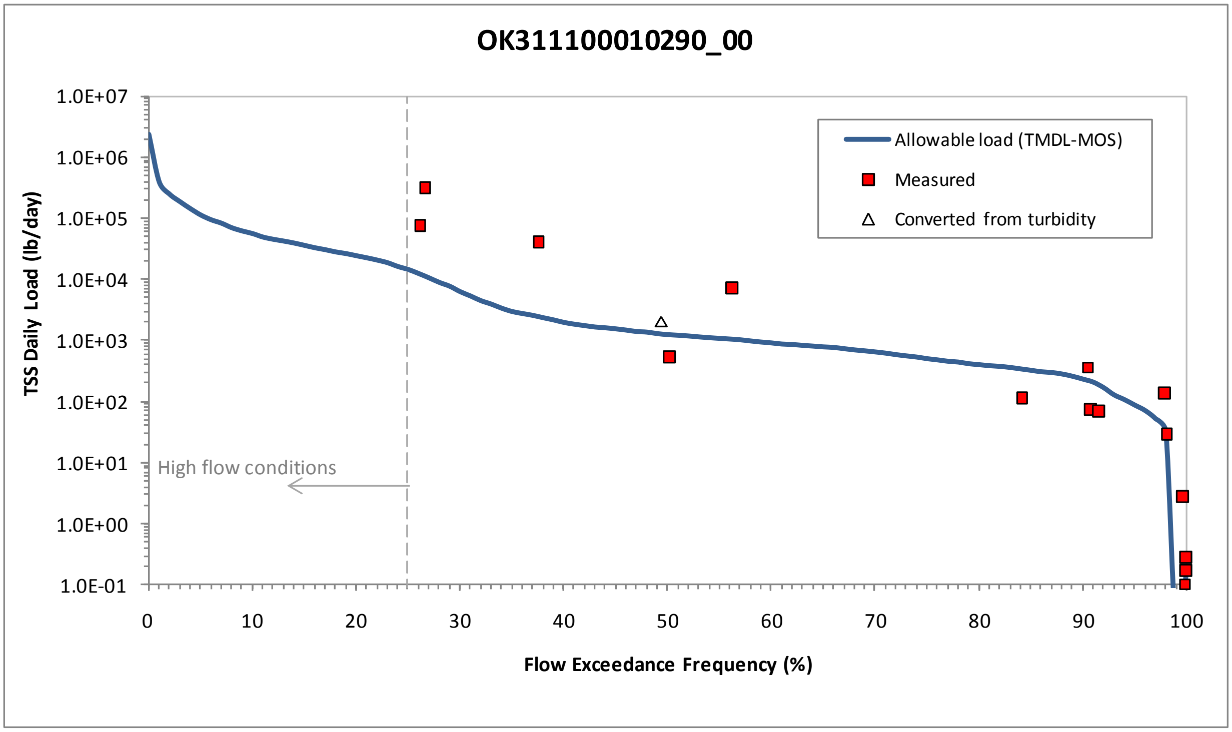


Figure 5-37 Load Duration Curve for Total Suspended Solids in Red Creek (OK311100010290_00)



Establishing Percent Reduction Goals: The LDC approach recognizes that the assimilative capacity of a waterbody depends on the flow, and that maximum allowable loading varies with flow condition. Existing loading and load reductions required to meet the TMDL water quality target can also be calculated under different flow conditions. The difference between existing loading and the water quality target is used to calculate the loading reductions required. Percent reduction goals are calculated through an iterative process of taking a series of percent reduction values applying each value uniformly between the concentrations of samples and verifying that no more than a fixed percent of the samples exceed the water quality target concentration. PRG are calculated for each watershed and bacterial indicator species as the reductions in load required so no existing instantaneous water quality observations would exceed the water quality targets for *E. coli* and Enterococci and no more than 25 percent of the samples exceed the water quality target for fecal coliform. This is because for the PBCR use to be supported, criteria for each bacterial indicator must be met in each impaired waterbody. Table 5-1 presents the percent reductions necessary to meet the TMDL water quality target for each bacterial indicator in each of the impaired waterbodies in the Study Area. The PRGs range from 13 to 99 percent.

Table 5-1 TMDL Percent Reductions Required to Meet Water Quality Standards for Indicator Bacteria

Waterbody ID	Waterbody Name	Required Reduction Rate				
		FC	EC		ENT	
		Instant-aneous	Instant-aneous	Geo-mean	Instant-aneous	Geo-mean
OK311800000040_00	Haystack Creek		83%	**39%**	98%	**87%**
OK311600010020_00	Gypsum Creek				87%	**86%**
OK311510020120_00	Sweetwater Creek		**64%**	68%	**77%**	86%
OK311510010010_10	North Fork of the Red River, SH 34, Carter				96%	**13%**
OK311500010080_00	Otter Creek		82%	**36%**	96%	**81%**
OK311310030010_00	Deep Red Creek		97%	**36%**	99%	**81%**
OK311200000030_00	Beaver Creek				93%	**68%**
OK311100010290_00	Red Creek		93%	**34%**	99%	**86%**

Similarly, percent reduction goals for TSS are calculated as the required overall reduction so that no more than 10 percent of the samples exceed the water quality target for TSS. The PRGs for the fourteen waterbodies included in this TMDL report are summarized in Table 5-2 and range from 6 to 95 percent.

Table 5-2 TMDL Percent Reductions Required to Meet Water Quality Targets for Total Suspended Solids

Waterbody ID	Waterbody Name	Required Reduction Rate
OK311800000070_00	Deer Creek	60%
OK311800000040_00	Haystack Creek	50%
OK311600010040_00	Sandy Creek (Lebos)	67%
OK311600010020_00	Gypsum Creek	58%
OK311510020120_00	Sweetwater Creek	36%
OK311510010010_10	North Fork of the Red River, SH 34, Carter	6%
OK311500030010_00	Elk Creek, SH 19, Roosevelt	86%
OK311500010080_00	Otter Creek	62%
OK311500010050_00	Stinking Creek	62%
OK311500010020_10	North Fork of the Red River, US 62, Headrick	40%
OK311310030050_00	Brush Creek	81%
OK311310030040_00	Little Deep Red Creek	76%
OK311310030010_00	Deep Red Creek	75%
OK311310020010_00	West Cache Creek, SH5B, Taylor	65%
OK311310010070_00	Suttle Creek	65%
OK311300010020_10	East Cache Creek, SH 53, Walters	62%
OK311300010020_00	Cache Creek, East	83%
OK311200000080_00	Dry Creek	75%
OK311200000060_00	Cow Creek	80%
OK311200000030_00	Beaver Creek	59%
OK311100040080_00	Mud Creek, Lower West	95%
OK311100040010_00	Mud Creek	88%
OK311100010300_00	Fleetwood Creek	77%
OK311100010290_00	Red Creek	94%

5.2 Wasteload Allocation

5.2.1 Indicator Bacteria

For bacteria TMDLs, NPDES-permitted facilities are allocated a daily wasteload calculated as their permitted flow rate multiplied by the instream geometric mean water quality criterion. In other words, the facilities are required to meet instream criteria in their discharge. Table 5-3 summarizes the WLA for the NPDES-permitted facilities within the Red River Study Area. The WLA for each facility discharging to a bacteria-impaired reach is derived from the following equation:

WLA = WQS * flow * unit conversion factor (#/day)

Where:

WQS = 33, 200, and 126 cfu/100 mL for Enterococci, fecal coliform, and E. coli respectively

flow (10^6 gal/day) = permitted flow

unit conversion factor = 37,854,120-10^6gal/day

When multiple NPDES facilities occur within a watershed, individual WLAs are summed and the total WLA for continuous point sources is included in the TMDL calculation for the corresponding waterbody. When there are no NPDES WWTPs discharging into the contributing watershed of a WQM station, then the WLA is zero. Compliance with the WLA will be achieved by adhering to the fecal coliform limits and disinfection requirements of NPDES permits. There are no NPDES WWTPs discharging into the contributing watersheds of stream segments that require bacteria TMDLs.

Permitted stormwater discharges are considered point sources; however, there are no areas designated as MS4s within the watersheds of the waterbodies impaired for contact recreation, so the WLA for MS4 is zero.

5.2.2 Total Suspended Solids

NPDES-permitted facilities discharging inorganic TSS are allocated a daily wasteload calculated by using the average of self-reported monthly flow multiplied by the water quality target. In other words, the facilities are required to meet instream criteria in their discharge. If the current monthly TSS limits of a facility are greater than instream TSS criteria, the new limits equal to instream criteria will be applied to the facility as their permit is renewed. Table 5-3 summarizes the WLA for the two NPDES-permitted facilities within the Red River Study Area. The WLA for each facility is derived as follows:

WLA_WWTP = WQ goal * flow * unit conversion factor (lb/day)

Where:

WQ goal = waterbody-specific water quality goal as summarized in Table 4-1

flow (10^6 gal/day) = average monthly flow

unit conversion factor = 8.3445 L*lb/(10^6 gal * mg)

Table 5-3 Total Suspended Solids Wasteload Allocations for NPDES-Permitted Facilities

Waterbody ID	Instream TSS Criteria (mg/L)	NPDES Permit No.	Name	Average Monthly Flow (mgd)	Wasteload Allocation (lb/day)
OK311500010080_00	41	OKG950015	Meridian Aggregates Company	0.005	2

No wasteload allocations are needed for stormwater dischargers in the Study Area. By definition, any stormwater discharge occurs during periods of rainfall and elevated flow conditions. Oklahoma's Water Quality Standards specify that the criteria for turbidity "apply only to seasonal base flow conditions" and go on to say "Elevated turbidity levels may be expected during, and for several days after, a runoff event" [OAC 785:45-5-12(f)(7)]. To accommodate the potential for future growth in those watersheds with no WLA for TSS, 1 percent of TSS loading is reserved as part of the WLA.

5.3 Load Allocation

As discussed in Section 3, nonpoint source bacteria loading to each waterbody emanate from a number of different sources. The data analysis and the LDCs indicate that exceedances for each waterbody are the result of a variety of nonpoint source loading. The LAs for each bacterial indicator in waterbodies not supporting the PBCR use are calculated as the difference between the TMDL, MOS, and WLA, as follows:

LA = TMDL – WLA_WWTP– MOS

This equation is used to calculate the LA for TSS however the LA is further reduced by allocating 1 pecent of the TMDL as part of the WLA:

LA = TMDL – WLA_WWTP – WLA_growth – MOS

5.4 Seasonal Variability

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. The bacteria TMDLs established in this report adhere to the seasonal application of the Oklahoma WQS which limits the PBCR use to the period of May 1st through September 30th. Similarly, the turbidity TMDLs established in this report adhere to the seasonal application of the Oklahoma WQS for turbidity, which applies to seasonal base flow conditions only. Seasonal variation was also accounted for in these TMDLs by using more than five years of water quality data and by using the longest period of USGS flow records when estimating flows to develop flow exceedance percentiles.

5.5 Margin of Safety

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs include an MOS. The MOS is a conservative measure incorporated into the TMDL equation that accounts for the lack of knowledge associated with calculating the allowable pollutant loading to ensure WQSs are attained. USEPA guidance allows for use of implicit or explicit expressions of the MOS, or both. When conservative assumptions are used in development of the TMDL, or conservative factors are used in the calculations, the MOS is implicit. When a specific percentage of the TMDL is set aside to account for the lack of knowledge, then the MOS is considered explicit.

For bacteria TMDLs, an explicit MOS was set at 10 percent.

For turbidity, the TMDLs are calculated for TSS instead of turbidity. Thus, the quality of the regression has a direct impact on confidence of the TMDL calculations. The better the regression is, the more confidence there is in the TMDL targets. As a result, it leads to a smaller margin of safety. The selection of MOS is based on the NRMSE for each waterbody. The explicit MOS ranges from 10 percent to 25 percent. Table 5-4 shows the MOS for each waterbody.

Table 5-4 Explicit Margin of Safety for Total Suspended Solids TMDLs

Waterbody ID	Waterbody Name	NRMSE	Margin of Safety
OK311800000070_00	Deer Creek	10.1%	15%
OK311800000040_00	Haystack Creek	16.7%	20%

Waterbody ID	Waterbody Name	NRMSE	Margin of Safety
OK311600010040_00	Sandy Creek (Lebos)	16.9%	20%
OK311600010020_00	Gypsum Creek	7.3%	10%
OK311510020120_00	Sweetwater Creek	6.5%	10%
OK311510010010_10	North Fork of the Red River, SH 34, Carter	24.3%	25%
OK311500030010_00	Elk Creek, SH 19, Roosevelt	13.0%	15%
OK311500010080_00	Otter Creek	6.8%	10%
OK311500010050_00	Stinking Creek	4.5%	10%
OK311500010020_10	North Fork of the Red River, US 62, Headrick	10.6%	15%
OK311310030050_00	Brush Creek	9.5%	10%
OK311310030040_00	Little Deep Red Creek	16.8%	20%
OK311310030010_00	Deep Red Creek	7.1%	10%
OK311310020010_00	West Cache Creek, SH5B, Taylor	21.7%	25%
OK311310010070_00	Suttle Creek	5.0%	10%
OK311300010020_10	East Cache Creek, SH 53, Walters	13.3%	15%
OK311300010020_00	Cache Creek, East	6.8%	10%
OK311200000080_00	Dry Creek	26.8%	25%
OK311200000060_00	Cow Creek	8.4%	10%
OK311200000030_00	Beaver Creek	8.5%	10%
OK311100040080_00	Mud Creek, Lower West	23.0%	25%
OK311100040010_00	Mud Creek	6.4%	10%
OK311100010300_00	Fleetwood Creek	6.4%	10%
OK311100010290_00	Red Creek	6.8%	10%

5.6 TMDL Calculations

The TMDLs for the 303(d)-listed waterbodies covered in this report were derived using LDCs. A TMDL is expressed as the sum of all WLAs (point source loads), LAs (nonpoint source loads), and an appropriate MOS, which attempts to account for the lack of knowledge concerning the relationship between effluent limitations and water quality.

This definition can be expressed by the following equation:

$$TMDL = \Sigma\, WLA + \Sigma\, LA + MOS$$

The TMDL represents a continuum of desired load over all flow conditions, rather than fixed at a single value, because loading capacity varies as a function of the flow present in the stream. The higher the flow is, the more wasteload the stream can handle without violating water quality standards. Regardless of the magnitude of the WLA calculated in these TMDLs, future new discharges or increased load from existing discharges will be considered consistent with the TMDL provided the NPDES permit requires instream criteria to be met.

The TMDL, WLA, LA, and MOS will vary with flow condition, and are calculated at every 5^{th} flow interval percentile. Tables 5-5 through 5-17 summarize the allocations for indicator bacteria and Tables 5-18 to 5-41 present the allocations for total suspended solids.

Table 5-5 *E. coli* TMDL Calculations for Haystack Creek (OK311800000040_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	30,487	3.03E+14	0	2.73E+14	3.03E+13
5	1,465	1.45E+13	0	1.31E+13	1.45E+12
10	727	7.22E+12	0	6.50E+12	7.22E+11
15	466	4.63E+12	0	4.17E+12	4.63E+11
20	316	3.14E+12	0	2.82E+12	3.14E+11
25	188	1.87E+12	0	1.68E+12	1.87E+11
30	81.7	8.11E+11	0	7.30E+11	8.11E+10
35	38.7	3.84E+11	0	3.46E+11	3.84E+10
40	25.6	2.55E+11	0	2.29E+11	2.55E+10
45	20.1	2.00E+11	0	1.80E+11	2.00E+10
50	16.2	1.61E+11	0	1.45E+11	1.61E+10
55	14.0	1.40E+11	0	1.26E+11	1.40E+10
60	11.8	1.18E+11	0	1.06E+11	1.18E+10
65	10.2	1.01E+11	0	9.12E+10	1.01E+10
70	08.4	8.38E+10	0	7.54E+10	8.38E+09
75	6.5	6.50E+10	0	5.85E+10	6.50E+09
80	5.2	5.19E+10	0	4.67E+10	5.19E+09
85	4.2	4.20E+10	0	3.78E+10	4.20E+09
90	3.0	3.01E+10	0	2.71E+10	3.01E+09
95	1.1	1.13E+10	0	1.02E+10	1.13E+09
100	0.0	0	0	0	0

Table 5-6 Enterococci TMDL Calculations for Haystack Creek (OK311800000040_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	30,487	8.06E+13	0	7.25E+13	8.06E+12
5	1,465	3.87E+12	0	3.48E+12	3.87E+11
10	727	1.92E+12	0	1.73E+12	1.92E+11
15	466	1.23E+12	0	1.11E+12	1.23E+11
20	316	8.35E+11	0	7.51E+11	8.35E+10
25	188	4.97E+11	0	4.47E+11	4.97E+10
30	81.7	2.16E+11	0	1.94E+11	2.16E+10
35	38.7	1.02E+11	0	9.19E+10	1.02E+10
40	25.6	6.77E+10	0	6.10E+10	6.77E+09
45	20.1	5.31E+10	0	4.78E+10	5.31E+09
50	16.2	4.28E+10	0	3.85E+10	4.28E+09
55	14.0	3.71E+10	0	3.34E+10	3.71E+09
60	11.8	3.13E+10	0	2.82E+10	3.13E+09
65	10.2	2.69E+10	0	2.43E+10	2.69E+09
70	8.4	2.23E+10	0	2.01E+10	2.23E+09
75	6.5	1.73E+10	0	1.56E+10	1.73E+09
80	5.2	1.38E+10	0	1.24E+10	1.38E+09
85	4.2	1.12E+10	0	1.01E+10	1.12E+09
90	3.0	8.02E+09	0	7.22E+09	8.02E+08
95	1.1	3.02E+09	0	2.72E+09	3.02E+08
100	0.0	0	0	0	0

Table 5-7 Enterococci TMDL Calculations for Gypsum Creek (OK311600010020_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	23,657	6.25E+13	0	5.63E+13	6.25E+12
5	1,137	3.00E+12	0	2.70E+12	3.00E+11
10	564	1.49E+12	0	1.34E+12	1.49E+11
15	362	9.56E+11	0	8.61E+11	9.56E+10
20	245	6.48E+11	0	5.83E+11	6.48E+10
25	146	3.85E+11	0	3.47E+11	3.85E+10
30	63.4	1.67E+11	0	1.51E+11	1.67E+10
35	30.0	7.93E+10	0	7.13E+10	7.93E+09
40	19.9	5.26E+10	0	4.73E+10	5.26E+09
45	15.6	4.12E+10	0	3.71E+10	4.12E+09
50	12.6	3.32E+10	0	2.99E+10	3.32E+09
55	10.9	2.88E+10	0	2.59E+10	2.88E+09
60	9.2	2.43E+10	0	2.19E+10	2.43E+09
65	7.9	2.09E+10	0	1.88E+10	2.09E+09
70	6.5	1.73E+10	0	1.56E+10	1.73E+09
75	5.1	1.34E+10	0	1.21E+10	1.34E+09
80	4.1	1.07E+10	0	9.64E+09	1.07E+09
85	3.3	8.67E+09	0	7.80E+09	8.67E+08
90	2.4	6.22E+09	0	5.60E+09	6.22E+08
95	0.89	2.34E+09	0	2.11E+09	2.34E+08
100	0.0	0	0	0	0

Table 5-8 *E. coli* TMDL Calculations for Sweetwater Creek (OK311510020120_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	961	9.54E+12	0	8.59E+12	9.54E+11
5	78.9	7.84E+11	0	7.05E+11	7.84E+10
10	57.3	5.69E+11	0	5.12E+11	5.69E+10
15	47.1	4.68E+11	0	4.21E+11	4.68E+10
20	42.0	4.17E+11	0	3.75E+11	4.17E+10
25	36.9	3.67E+11	0	3.30E+11	3.67E+10
30	34.4	3.41E+11	0	3.07E+11	3.41E+10
35	30.5	3.03E+11	0	2.73E+11	3.03E+10
40	28.0	2.78E+11	0	2.50E+11	2.78E+10
45	26.7	2.65E+11	0	2.39E+11	2.65E+10
50	24.2	2.40E+11	0	2.16E+11	2.40E+10
55	21.6	2.15E+11	0	1.93E+11	2.15E+10
60	19.1	1.90E+11	0	1.71E+11	1.90E+10
65	16.5	1.64E+11	0	1.48E+11	1.64E+10
70	14.0	1.39E+11	0	1.25E+11	1.39E+10
75	10.9	1.09E+11	0	9.78E+10	1.09E+10
80	7.4	7.33E+10	0	6.60E+10	7.33E+09
85	4.6	4.55E+10	0	4.10E+10	4.55E+09
90	2.5	2.53E+10	0	2.28E+10	2.53E+09
95	0.94	9.35E+09	0	8.42E+09	9.35E+08
100	0.0	0	0	0	0

Table 5-9 Enterococci TMDL Calculations for Sweetwater Creek (OK311510020120_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	961	2.54E+12	0	2.28E+12	2.54E+11
5	78.9	2.08E+11	0	1.88E+11	2.08E+10
10	57.3	1.51E+11	0	1.36E+11	1.51E+10
15	47.1	1.24E+11	0	1.12E+11	1.24E+10
20	42.0	1.11E+11	0	9.99E+10	1.11E+10
25	36.9	9.75E+10	0	8.78E+10	9.75E+09
30	34.4	9.08E+10	0	8.17E+10	9.08E+09
35	30.5	8.07E+10	0	7.26E+10	8.07E+09
40	28.0	7.40E+10	0	6.66E+10	7.40E+09
45	26.7	7.06E+10	0	6.35E+10	7.06E+09
50	24.2	6.39E+10	0	5.75E+10	6.39E+09
55	21.6	5.72E+10	0	5.14E+10	5.72E+09
60	19.1	5.04E+10	0	4.54E+10	5.04E+09
65	16.5	4.37E+10	0	3.93E+10	4.37E+09
70	14.0	3.70E+10	0	3.33E+10	3.70E+09
75	10.9	2.89E+10	0	2.60E+10	2.89E+09
80	7.4	1.95E+10	0	1.76E+10	1.95E+09
85	4.6	1.21E+10	0	1.09E+10	1.21E+09
90	2.5	6.72E+09	0	6.05E+09	6.72E+08
95	0.94	2.49E+09	0	2.24E+09	2.49E+08
100	0.0	0	0	0	0

Table 5-10 Enterococci TMDL Calculations for the Red River, North Fork (OK311510010010_10)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	801,696	2.12E+15	9.37E+07	1.91E+15	2.12E+14
5	14,523	3.84E+13	9.37E+07	3.45E+13	3.84E+12
10	8,598	2.27E+13	9.37E+07	2.04E+13	2.27E+12
15	6,507	1.72E+13	9.37E+07	1.55E+13	1.72E+12
20	5,151	1.36E+13	9.37E+07	1.22E+13	1.36E+12
25	4,183	1.11E+13	9.37E+07	9.95E+12	1.11E+12
30	3,524	9.31E+12	9.37E+07	8.38E+12	9.31E+11
35	2,943	7.78E+12	9.37E+07	7.00E+12	7.78E+11
40	2,401	6.34E+12	9.37E+07	5.71E+12	6.34E+11
45	1,975	5.22E+12	9.37E+07	4.70E+12	5.22E+11
50	1,627	4.30E+12	9.37E+07	3.87E+12	4.30E+11
55	1,278	3.38E+12	9.37E+07	3.04E+12	3.38E+11
60	930	2.46E+12	9.37E+07	2.21E+12	2.46E+11
65	658	1.74E+12	9.37E+07	1.57E+12	1.74E+11
70	387	1.02E+12	9.37E+07	9.21E+11	1.02E+11
75	174	4.61E+11	9.37E+07	4.14E+11	4.61E+10
80	31.0	8.19E+10	9.37E+07	7.37E+10	8.19E+09
85	0.0	1.04E+08	9.37E+07	0	1.04E+07
90	0.0	1.04E+08	9.37E+07	0	1.04E+07
95	0.0	1.04E+08	9.37E+07	0	1.04E+07
100	0.0	1.04E+08	9.37E+07	0	1.04E+07

Table 5-11 *E. coli* TMDL Calculations for Otter Creek (OK311500010080_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	3,720	3.70E+13	0	3.33E+13	3.70E+12
5	85.0	8.44E+11	0	7.60E+11	8.44E+10
10	23.0	2.28E+11	0	2.06E+11	2.28E+10
15	12.0	1.19E+11	0	1.07E+11	1.19E+10
20	8.5	8.44E+10	0	7.60E+10	8.44E+09
25	6.4	6.36E+10	0	5.72E+10	6.36E+09
30	5.2	5.17E+10	0	4.65E+10	5.17E+09
35	4.2	4.17E+10	0	3.75E+10	4.17E+09
40	3.4	3.38E+10	0	3.04E+10	3.38E+09
45	2.6	2.58E+10	0	2.32E+10	2.58E+09
50	1.6	1.59E+10	0	1.43E+10	1.59E+09
55	1.1	1.09E+10	0	9.83E+09	1.09E+09
60	0.74	7.35E+09	0	6.62E+09	7.35E+08
65	0.49	4.87E+09	0	4.38E+09	4.87E+08
70	0.26	2.58E+09	0	2.32E+09	2.58E+08
75	0.05	4.97E+08	0	4.47E+08	4.97E+07
80	0.0	0	0	0	0
85	0.0	0	0	0	0
90	0.0	0	0	0	0
95	0.0	0	0	0	0
100	0.0	0	0	0	0

Table 5-12 Enterococci TMDL Calculations for Otter Creek (OK311500010080_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	3,720	9.83E+12	0	8.85E+12	9.83E+11
5	85.0	2.25E+11	0	2.02E+11	2.25E+10
10	23.0	6.08E+10	0	5.47E+10	6.08E+09
15	12.0	3.17E+10	0	2.85E+10	3.17E+09
20	8.5	2.25E+10	0	2.02E+10	2.25E+09
25	6.4	1.69E+10	0	1.52E+10	1.69E+09
30	5.2	1.37E+10	0	1.24E+10	1.37E+09
35	4.2	1.11E+10	0	9.99E+09	1.11E+09
40	3.4	8.98E+09	0	8.09E+09	8.98E+08
45	2.6	6.87E+09	0	6.18E+09	6.87E+08
50	1.6	4.23E+09	0	3.80E+09	4.23E+08
55	1.1	2.91E+09	0	2.62E+09	2.91E+08
60	0.74	1.96E+09	0	1.76E+09	1.96E+08
65	0.49	1.29E+09	0	1.17E+09	1.29E+08
70	0.26	6.87E+08	0	6.18E+08	6.87E+07
75	0.05	1.32E+08	0	1.19E+08	1.32E+07
80	0.0	0	0	0	0
85	0.0	0	0	0	0
90	0.0	0	0	0	0
95	0.0	0	0	0	0
100	0.0	0	0	0	0

Table 5-13 *E. coli* TMDL Calculations for Deep Red Creek (OK311310030010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	46,300	4.60E+14	0	4.14E+14	4.60E+13
5	626	6.22E+12	0	5.60E+12	6.22E+11
10	173	1.72E+12	0	1.55E+12	1.72E+11
15	74.0	7.35E+11	0	6.62E+11	7.35E+10
20	39.0	3.87E+11	0	3.49E+11	3.87E+10
25	23.0	2.28E+11	0	2.06E+11	2.28E+10
30	15.0	1.49E+11	0	1.34E+11	1.49E+10
35	11.0	1.09E+11	0	9.83E+10	1.09E+10
40	8.1	8.05E+10	0	7.24E+10	8.05E+09
45	6.2	6.16E+10	0	5.54E+10	6.16E+09
50	4.8	4.77E+10	0	4.29E+10	4.77E+09
55	3.8	3.77E+10	0	3.40E+10	3.77E+09
60	2.9	2.88E+10	0	2.59E+10	2.88E+09
65	2.2	2.19E+10	0	1.97E+10	2.19E+09
70	1.6	1.59E+10	0	1.43E+10	1.59E+09
75	1.0	9.93E+09	0	8.94E+09	9.93E+08
80	0.6	5.96E+09	0	5.36E+09	5.96E+08
85	0.2	1.99E+09	0	1.79E+09	1.99E+08
90	0.0	0	0	0	0
95	0.0	0	0	0	0
100	0.0	0	0	0	0

Table 5-14 Enterococci TMDL Calculations for Deep Red Creek (OK311310030010_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	46,300	1.22E+14	0	1.10E+14	1.22E+13
5	626	1.65E+12	0	1.49E+12	1.65E+11
10	173	4.57E+11	0	4.11E+11	4.57E+10
15	74.0	1.96E+11	0	1.76E+11	1.96E+10
20	39.0	1.03E+11	0	9.27E+10	1.03E+10
25	23.0	6.08E+10	0	5.47E+10	6.08E+09
30	15.0	3.96E+10	0	3.57E+10	3.96E+09
35	11.0	2.91E+10	0	2.62E+10	2.91E+09
40	8.1	2.14E+10	0	1.93E+10	2.14E+09
45	6.2	1.64E+10	0	1.47E+10	1.64E+09
50	4.8	1.27E+10	0	1.14E+10	1.27E+09
55	3.8	1.00E+10	0	9.04E+09	1.00E+09
60	2.9	7.66E+09	0	6.90E+09	7.66E+08
65	2.2	5.81E+09	0	5.23E+09	5.81E+08
70	1.6	4.23E+09	0	3.80E+09	4.23E+08
75	1.0	2.64E+09	0	2.38E+09	2.64E+08
80	0.6	1.59E+09	0	1.43E+09	1.59E+08
85	0.2	5.28E+08	0	4.76E+08	5.28E+07
90	0.0	0	0	0	0
95	0.0	0	0	0	0
100	0.0	0	0	0	0

Table 5-15 Enterococci TMDL Calculations for Beaver Creek (OK311200000030_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	34600	9.14E+13	0	8.23E+13	9.14E+12
5	871	2.30E+12	0	2.07E+12	2.30E+11
10	412	1.09E+12	0	9.80E+11	1.09E+11
15	227	6.00E+11	0	5.40E+11	6.00E+10
20	142	3.75E+11	0	3.38E+11	3.75E+10
25	95.0	2.51E+11	0	2.26E+11	2.51E+10
30	71.0	1.88E+11	0	1.69E+11	1.88E+10
35	57.0	1.51E+11	0	1.36E+11	1.51E+10
40	48.0	1.27E+11	0	1.14E+11	1.27E+10
45	42.0	1.11E+11	0	9.99E+10	1.11E+10
50	38.0	1.00E+11	0	9.04E+10	1.00E+10
55	33.0	8.72E+10	0	7.85E+10	8.72E+09
60	30.0	7.93E+10	0	7.13E+10	7.93E+09
65	26.0	6.87E+10	0	6.18E+10	6.87E+09
70	23.0	6.08E+10	0	5.47E+10	6.08E+09
75	20.0	5.28E+10	0	4.76E+10	5.28E+09
80	18.0	4.76E+10	0	4.28E+10	4.76E+09
85	15.0	3.96E+10	0	3.57E+10	3.96E+09
90	12.0	3.17E+10	0	2.85E+10	3.17E+09
95	7.4	1.96E+10	0	1.76E+10	1.96E+09
100	0.0	0	0	0	0

Table 5-16 *E. coli* TMDL Calculations for Red Creek (OK311100010290_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	14,368	1.43E+14	0	1.28E+14	1.43E+13
5	690	6.86E+12	0	6.17E+12	6.86E+11
10	343	3.40E+12	0	3.06E+12	3.40E+11
15	220	2.18E+12	0	1.97E+12	2.18E+11
20	149	1.48E+12	0	1.33E+12	1.48E+11
25	88.6	8.80E+11	0	7.92E+11	8.80E+10
30	38.5	3.82E+11	0	3.44E+11	3.82E+10
35	18.2	1.81E+11	0	1.63E+11	1.81E+10
40	12.1	1.20E+11	0	1.08E+11	1.20E+10
45	9.5	9.41E+10	0	8.47E+10	9.41E+09
50	7.6	7.58E+10	0	6.82E+10	7.58E+09
55	6.6	6.58E+10	0	5.92E+10	6.58E+09
60	5.6	5.55E+10	0	4.99E+10	5.55E+09
65	4.8	4.77E+10	0	4.30E+10	4.77E+09
70	4.0	3.95E+10	0	3.55E+10	3.95E+09
75	3.1	3.06E+10	0	2.76E+10	3.06E+09
80	2.5	2.44E+10	0	2.20E+10	2.44E+09
85	2.0	1.98E+10	0	1.78E+10	1.98E+09
90	1.4	1.42E+10	0	1.28E+10	1.42E+09
95	0.54	5.35E+09	0	4.81E+09	5.35E+08
100	0.00	0	0	0	0

Table 5-17 Enterococci TMDL Calculations for Red Creek (OK311100010290_00)

Percentile	Flow (cfs)	TMDL (cfu/day)	WLA_{WWTP} (cfu/day)	LA (cfu/day)	MOS (cfu/day)
0	14,368	3.80E+13	0	3.42E+13	3.80E+12
5	690	1.82E+12	0	1.64E+12	1.82E+11
10	343	9.06E+11	0	8.15E+11	9.06E+10
15	220	5.81E+11	0	5.23E+11	5.81E+10
20	149	3.93E+11	0	3.54E+11	3.93E+10
25	88.6	2.34E+11	0	2.11E+11	2.34E+10
30	38.5	1.02E+11	0	9.15E+10	1.02E+10
35	18.2	4.81E+10	0	4.33E+10	4.81E+09
40	12.1	3.19E+10	0	2.87E+10	3.19E+09
45	9.5	2.50E+10	0	2.25E+10	2.50E+09
50	7.6	2.02E+10	0	1.81E+10	2.02E+09
55	6.6	1.75E+10	0	1.57E+10	1.75E+09
60	5.6	1.48E+10	0	1.33E+10	1.48E+09
65	4.8	1.27E+10	0	1.14E+10	1.27E+09
70	4.0	1.05E+10	0	9.45E+09	1.05E+09
75	3.1	8.15E+09	0	7.33E+09	8.15E+08
80	2.5	6.50E+09	0	5.85E+09	6.50E+08
85	2.0	5.26E+09	0	4.74E+09	5.26E+08
90	1.4	3.78E+09	0	3.40E+09	3.78E+08
95	0.54	1.42E+09	0	1.28E+09	1.42E+08
100	0.00	0	0	0	0

Table 5-18 Total Suspended Solids TMDL Calculations for Deer Creek (OK311800000070_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	10,503	NA	NA	NA	NA	NA
5	505	NA	NA	NA	NA	NA
10	251	NA	NA	NA	NA	NA
15	161	NA	NA	NA	NA	NA
20	109	NA	NA	NA	NA	NA
25	65	16,099	0	161	13,523	2,415
30	28	6,992	0	70	5,873	1,049
35	13	3,310	0	33	2,781	497
40	9	2,195	0	22	1,844	329
45	7	1,722	0	17	1,446	258
50	6	1,386	0	14	1,164	208
55	5	1,203	0	12	1,011	180
60	4	1,014	0	10	852	152
65	4	873	0	9	734	131
70	3	722	0	7	607	108
75	2	560	0	6	471	84
80	2	447	0	4	376	67
85	1	362	0	4	304	54
90	1	260	0	3	218	39
95	0	98	0	1	82	15
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-19 Total Suspended Solids TMDL Calculations for Haystack Creek (OK311800000040_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	30,487	NA	NA	NA	NA	NA
5	1,465	NA	NA	NA	NA	NA
10	727	NA	NA	NA	NA	NA
15	466	NA	NA	NA	NA	NA
20	316	NA	NA	NA	NA	NA
25	188	48,870	0	489	38,608	9,774
30	82	21,226	0	212	16,769	4,245
35	39	10,049	0	100	7,939	2,010
40	26	6,664	0	67	5,265	1,333
45	20	5,226	0	52	4,129	1,045
50	16	4,208	0	42	3,324	842
55	14	3,652	0	37	2,885	730
60	12	3,080	0	31	2,433	616
65	10	2,651	0	27	2,094	530
70	8	2,193	0	22	1,732	439
75	7	1,701	0	17	1,344	340
80	5	1,357	0	14	1,072	271
85	4	1,099	0	11	868	220
90	3	789	0	8	623	158
95	1	297	0	3	235	59
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-20 Total Suspended Solids TMDL Calculations for Sandy Creek (Lebos) (OK311600010040_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	82,922	NA	NA	NA	NA	NA
5	3,984	NA	NA	NA	NA	NA
10	1,978	NA	NA	NA	NA	NA
15	1,269	NA	NA	NA	NA	NA
20	859	NA	NA	NA	NA	NA
25	511	278,904	0	2,789	220,334	55,781
30	222	121,138	0	1,211	95,699	24,228
35	105	57,350	0	573	45,306	11,470
40	70	38,031	0	380	30,045	7,606
45	55	29,825	0	298	23,561	5,965
50	44	24,015	0	240	18,972	4,803
55	38	20,843	0	208	16,466	4,169
60	32	17,575	0	176	13,884	3,515
65	28	15,130	0	151	11,953	3,026
70	23	12,516	0	125	9,887	2,503
75	18	9,708	0	97	7,669	1,942
80	14	7,747	0	77	6,120	1,549
85	11	6,270	0	63	4,953	1,254
90	8	4,503	0	45	3,557	901
95	3	1,695	0	17	1,339	339
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-21 Total Suspended Solids TMDL Calculations for Gypsum Creek (OK311600010020_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	23,657	NA	NA	NA	NA	NA
5	1,137	NA	NA	NA	NA	NA
10	564	NA	NA	NA	NA	NA
15	362	NA	NA	NA	NA	NA
20	245	NA	NA	NA	NA	NA
25	146	55,236	0	552	49,160	5,524
30	63	23,991	0	240	21,352	2,399
35	30	11,358	0	114	10,109	1,136
40	20	7,532	0	75	6,703	753
45	16	5,907	0	59	5,257	591
50	13	4,756	0	48	4,233	476
55	11	4,128	0	41	3,674	413
60	9	3,481	0	35	3,098	348
65	8	2,996	0	30	2,667	300
70	7	2,479	0	25	2,206	248
75	5	1,923	0	19	1,711	192
80	4	1,534	0	15	1,365	153
85	3	1,242	0	12	1,105	124
90	2	892	0	9	794	89
95	1	336	0	3	299	34
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-22 Total Suspended Solids TMDL Calculations for Sweetwater Creek (OK311510020120_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	961	NA	NA	NA	NA	NA
5	79	NA	NA	NA	NA	NA
10	57	NA	NA	NA	NA	NA
15	47	NA	NA	NA	NA	NA
20	42	NA	NA	NA	NA	NA
25	37	14,740	0	147	13,119	1,474
30	34	13,724	0	137	12,214	1,372
35	31	12,199	0	122	10,857	1,220
40	28	11,182	0	112	9,952	1,118
45	27	10,674	0	107	9,500	1,067
50	24	9,657	0	97	8,595	966
55	22	8,641	0	86	7,690	864
60	19	7,624	0	76	6,786	762
65	17	6,608	0	66	5,881	661
70	14	5,591	0	56	4,976	559
75	11	4,371	0	44	3,890	437
80	7	2,948	0	29	2,624	295
85	5	1,830	0	18	1,629	183
90	3	1,017	0	10	905	102
95	1	377	0	4	335	38
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-23 Total Suspended Solids TMDL Calculations for the Red River, North Fork, Carter (OK311510010010_10)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	801,696	NA	NA	NA	NA	NA
5	14,523	NA	NA	NA	NA	NA
10	8,598	NA	NA	NA	NA	NA
15	6,507	NA	NA	NA	NA	NA
20	5,151	NA	NA	NA	NA	NA
25	4,183	2,523,743	0	25,237	1,867,570	630,936
30	3,524	2,126,487	0	21,265	1,573,600	531,622
35	2,943	1,775,967	0	17,760	1,314,216	443,992
40	2,401	1,448,815	0	14,488	1,072,123	362,204
45	1,975	1,191,767	0	11,918	881,908	297,942
50	1,627	981,456	0	9,815	726,277	245,364
55	1,278	771,144	0	7,711	570,646	192,786
60	930	560,832	0	5,608	415,016	140,208
65	658	397,256	0	3,973	293,969	99,314
70	387	233,680	0	2,337	172,923	58,420
75	174	105,156	0	1,052	77,815	26,289
80	31	18,694	0	187	13,834	4,674
85	0	0	0	0	0	0
90	0	0	0	0	0	0
95	0	0	0	0	0	0
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-24 Total Suspended Solids TMDL Calculations for Elk Creek (OK311500030010_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	26,748	NA	NA	NA	NA	NA
5	361	NA	NA	NA	NA	NA
10	162	NA	NA	NA	NA	NA
15	100	NA	NA	NA	NA	NA
20	68	NA	NA	NA	NA	NA
25	52	17,766	0	178	14,924	2,665
30	42	14,300	0	143	12,012	2,145
35	35	12,133	0	121	10,192	1,820
40	29	9,966	0	100	8,372	1,495
45	24	8,233	0	82	6,916	1,235
50	20	6,933	0	69	5,824	1,040
55	16	5,633	0	56	4,732	845
60	14	4,767	0	48	4,004	715
65	11	3,813	0	38	3,203	572
70	8	2,903	0	29	2,439	435
75	6	2,210	0	22	1,856	331
80	4	1,517	0	15	1,274	227
85	3	867	0	9	728	130
90	1	347	0	3	291	52
95	0	42	0	0	36	6
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-25 Total Suspended Solids TMDL Calculations for Otter Creek (OK311500010080_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	3,720	NA	NA	NA	NA	NA
5	85	NA	NA	NA	NA	NA
10	23	NA	NA	NA	NA	NA
15	12	NA	NA	NA	NA	NA
20	8.5	NA	NA	NA	NA	NA
25	6.4	1,421	2	14	1,263	142
30	5.2	1,155	2	12	1,026	115
35	4.2	933	2	9	829	93
40	3.4	755	2	8	669	76
45	2.6	577	2	6	511	58
50	1.6	355	2	4	313	36
55	1.1	244	2	2	216	24
60	0.7	164	2	2	144	16
65	0.5	109	2	1	95	11
70	0.3	58	2	1	49	6
75	0.1	11	2	0	8	1
80	0.01	2	2	0	0	0
85	0.01	2	2	0	0	0
90	0.01	2	2	0	0	0
95	0.01	2	2	0	0	0
100	0.01	2	2	0	0	0

NA = Not Applicable

Table 5-26 Total Suspended Solids TMDL Calculations for Stinking Creek (OK311500010050_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	28,041	NA	NA	NA	NA	NA
5	1,347	NA	NA	NA	NA	NA
10	669	NA	NA	NA	NA	NA
15	429	NA	NA	NA	NA	NA
20	291	NA	NA	NA	NA	NA
25	173	63,765	0	638	56,751	6,376
30	75	27,695	0	277	24,649	2,770
35	36	13,112	0	131	11,669	1,311
40	24	8,695	0	87	7,739	869
45	18	6,819	0	68	6,069	682
50	15	5,490	0	55	4,886	549
55	13	4,765	0	48	4,241	477
60	11	4,018	0	40	3,576	402
65	9	3,459	0	35	3,079	346
70	8	2,861	0	29	2,547	286
75	6	2,219	0	22	1,975	222
80	5	1,771	0	18	1,576	177
85	4	1,433	0	14	1,276	143
90	3	1,029	0	10	916	103
95	1	388	0	4	345	39
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-27 Total Suspended Solids TMDL Calculations for the Red River, North Fork, Headrick (OK311500010020_10)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	27,953	NA	NA	NA	NA	NA
5	1,351	NA	NA	NA	NA	NA
10	668	NA	NA	NA	NA	NA
15	436	NA	NA	NA	NA	NA
20	320	NA	NA	NA	NA	NA
25	245	123,515	0	1,235	103,752	18,527
30	201	101,484	0	1,015	85,247	15,223
35	161	81,260	0	813	68,258	12,189
40	130	65,730	0	657	55,213	9,860
45	107	54,173	0	542	45,505	8,126
50	94	47,311	0	473	39,741	7,097
55	83	41,894	0	419	35,191	6,284
60	75	37,921	0	379	31,854	5,688
65	67	33,949	0	339	28,517	5,092
70	59	29,976	0	300	25,180	4,496
75	52	26,364	0	264	22,146	3,955
80	45	22,753	0	228	19,112	3,413
85	38	19,141	0	191	16,079	2,871
90	31	15,891	0	159	13,348	2,384
95	21	10,835	0	108	9,101	1,625
100	2	939	0	9	789	141

NA = Not Applicable

Table 5-28 Total Suspended Solids TMDL Calculations for Brush Creek (OK311310030050_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	5,929	NA	NA	NA	NA	NA
5	80	NA	NA	NA	NA	NA
10	22	NA	NA	NA	NA	NA
15	9	NA	NA	NA	NA	NA
20	5	NA	NA	NA	NA	NA
25	3	840	0	8	747	84
30	2	548	0	5	487	55
35	1	402	0	4	357	40
40	1	296	0	3	263	30
45	1	226	0	2	201	23
50	1	175	0	2	156	18
55	0	139	0	1	123	14
60	0	106	0	1	94	11
65	0	80	0	1	71	8
70	0	58	0	1	52	6
75	0	37	0	0	33	4
80	0	22	0	0	20	2
85	0	7	0	0	6	1
90	0	0	0	0	0	0
95	0	0	0	0	0	0
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-29 Total Suspended Solids TMDL Calculations for Little Deep Red Creek (OK311310030040_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	21,318	NA	NA	NA	NA	NA
5	288	NA	NA	NA	NA	NA
10	80	NA	NA	NA	NA	NA
15	34	NA	NA	NA	NA	NA
20	18	NA	NA	NA	NA	NA
25	11	1,911	0	19	1,509	382
30	7	1,246	0	12	984	249
35	5	914	0	9	722	183
40	4	673	0	7	532	135
45	3	515	0	5	407	103
50	2	399	0	4	315	80
55	2	316	0	3	249	63
60	1	241	0	2	190	48
65	1	183	0	2	144	37
70	1	133	0	1	105	27
75	0	84	0	1	66	17
80	0	49	0	0	39	10
85	0	17	0	0	14	3
90	0	0	0	0	0	0
95	0	0	0	0	0	0
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-30 Total Suspended Solids TMDL Calculations for Deep Red Creek (OK311310030010_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	46,300	NA	NA	NA	NA	NA
5	626	NA	NA	NA	NA	NA
10	173	NA	NA	NA	NA	NA
15	74	NA	NA	NA	NA	NA
20	39	NA	NA	NA	NA	NA
25	23	3,983	0	40	3,545	398
30	15	2,597	0	26	2,312	260
35	11	1,905	0	19	1,695	190
40	8	1,403	0	14	1,248	140
45	6	1,074	0	11	956	107
50	5	831	0	8	740	83
55	4	658	0	7	586	66
60	3	502	0	5	447	50
65	2	381	0	4	339	38
70	2	277	0	3	247	28
75	1	173	0	2	154	17
80	1	103	0	1	92	10
85	0	34	0	0	31	3
90	0	0	0	0	0	0
95	0	0	0	0	0	0
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-31 Total Suspended Solids TMDL Calculations for West Cache Creek (OK311310020010_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	21,668	NA	NA	NA	NA	NA
5	293	NA	NA	NA	NA	NA
10	81	NA	NA	NA	NA	NA
15	35	NA	NA	NA	NA	NA
20	18	NA	NA	NA	NA	NA
25	11	3,412	0	34	2,525	853
30	7	2,226	0	22	1,647	557
35	5	1,633	0	16	1,209	408
40	4	1,202	0	12	889	300
45	3	920	0	9	681	230
50	2	714	0	7	528	178
55	2	565	0	6	418	141
60	1	431	0	4	319	108
65	1	327	0	3	242	82
70	1	238	0	2	176	59
75	0	149	0	1	110	37
80	0	89	0	1	66	22
85	0	28	0	0	21	7
90	0	0	0	0	0	0
95	0	0	0	0	0	0
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-32 Total Suspended Solids TMDL Calculations for Suttle Creek (OK311310010070_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	14,558	NA	NA	NA	NA	NA
5	699	NA	NA	NA	NA	NA
10	347	NA	NA	NA	NA	NA
15	223	NA	NA	NA	NA	NA
20	151	NA	NA	NA	NA	NA
25	90	22,411	0	224	19,946	2,241
30	39	9,734	0	97	8,663	973
35	18	4,608	0	46	4,101	461
40	12	3,056	0	31	2,720	306
45	10	2,397	0	24	2,133	240
50	8	1,930	0	19	1,717	193
55	7	1,675	0	17	1,491	167
60	6	1,412	0	14	1,257	141
65	5	1,216	0	12	1,082	122
70	4	1,006	0	10	895	101
75	3	780	0	8	694	78
80	2	622	0	6	554	62
85	2	504	0	5	448	50
90	1	362	0	4	322	36
95	1	136	0	1	121	14
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-33 Total Suspended Solids TMDL Calculations for East Cache Creek (OK311300010020_10)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	39,651	NA	NA	NA	NA	NA
5	998	NA	NA	NA	NA	NA
10	472	NA	NA	NA	NA	NA
15	260	NA	NA	NA	NA	NA
20	163	NA	NA	NA	NA	NA
25	109	23,946	0	239	20,115	3,592
30	81	17,896	0	179	15,033	2,684
35	65	14,368	0	144	12,069	2,155
40	55	12,099	0	121	10,163	1,815
45	48	10,587	0	106	8,893	1,588
50	44	9,578	0	96	8,046	1,437
55	38	8,318	0	83	6,987	1,248
60	34	7,562	0	76	6,352	1,134
65	30	6,554	0	66	5,505	983
70	26	5,797	0	58	4,870	870
75	23	5,041	0	50	4,235	756
80	21	4,537	0	45	3,811	681
85	17	3,781	0	38	3,176	567
90	14	3,025	0	30	2,541	454
95	8	1,866	0	19	1,567	280
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-34 Total Suspended Solids TMDL Calculations for East Cache Creek (OK311300010020_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	41,908	NA	NA	NA	NA	NA
5	1,055	NA	NA	NA	NA	NA
10	499	NA	NA	NA	NA	NA
15	275	NA	NA	NA	NA	NA
20	172	NA	NA	NA	NA	NA
25	115	24,634	0	246	21,924	2,463
30	86	18,411	0	184	16,386	1,841
35	69	14,780	0	148	13,155	1,478
40	58	12,447	0	124	11,078	1,245
45	51	10,891	0	109	9,693	1,089
50	46	9,854	0	99	8,770	985
55	40	8,557	0	86	7,616	856
60	36	7,779	0	78	6,923	778
65	31	6,742	0	67	6,000	674
70	28	5,964	0	60	5,308	596
75	24	5,186	0	52	4,616	519
80	22	4,668	0	47	4,154	467
85	18	3,890	0	39	3,462	389
90	15	3,112	0	31	2,769	311
95	9	1,919	0	19	1,708	192
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-35 Total Suspended Solids TMDL Calculations for Dry Creek (OK311200000080_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	11,175	NA	NA	NA	NA	NA
5	537	NA	NA	NA	NA	NA
10	267	NA	NA	NA	NA	NA
15	171	NA	NA	NA	NA	NA
20	116	NA	NA	NA	NA	NA
25	69	15,056	0	151	11,142	3,764
30	30	6,539	0	65	4,839	1,635
35	14	3,096	0	31	2,291	774
40	9	2,053	0	21	1,519	513
45	7	1,610	0	16	1,191	403
50	6	1,296	0	13	959	324
55	5	1,125	0	11	833	281
60	4	949	0	9	702	237
65	4	817	0	8	604	204
70	3	676	0	7	500	169
75	2	524	0	5	388	131
80	2	418	0	4	309	105
85	2	338	0	3	250	85
90	1	243	0	2	180	61
95	0	92	0	1	68	23
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-36 Total Suspended Solids TMDL Calculations for Cow Creek (OK311200000060_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	9,748	NA	NA	NA	NA	NA
5	245	NA	NA	NA	NA	NA
10	116	NA	NA	NA	NA	NA
15	64	NA	NA	NA	NA	NA
20	40	NA	NA	NA	NA	NA
25	27	5,849	0	58	5,206	585
30	20	4,371	0	44	3,891	437
35	16	3,509	0	35	3,123	351
40	14	2,955	0	30	2,630	296
45	12	2,586	0	26	2,301	259
50	11	2,340	0	23	2,082	234
55	9	2,032	0	20	1,808	203
60	8	1,847	0	18	1,644	185
65	7	1,601	0	16	1,425	160
70	6	1,416	0	14	1,260	142
75	6	1,231	0	12	1,096	123
80	5	1,108	0	11	986	111
85	4	924	0	9	822	92
90	3	739	0	7	658	74
95	2	456	0	5	405	46
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-37 Total Suspended Solids TMDL Calculations for Beaver Creek (OK311200000030_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	34,600	NA	NA	NA	NA	NA
5	871	NA	NA	NA	NA	NA
10	412	NA	NA	NA	NA	NA
15	227	NA	NA	NA	NA	NA
20	142	NA	NA	NA	NA	NA
25	95	18,619	0	186	16,570	1,862
30	71	13,915	0	139	12,384	1,391
35	57	11,171	0	112	9,942	1,117
40	48	9,407	0	94	8,372	941
45	42	8,231	0	82	7,326	823
50	38	7,447	0	74	6,628	745
55	33	6,467	0	65	5,756	647
60	30	5,880	0	59	5,233	588
65	26	5,096	0	51	4,535	510
70	23	4,508	0	45	4,012	451
75	20	3,920	0	39	3,489	392
80	18	3,528	0	35	3,140	353
85	15	2,940	0	29	2,616	294
90	12	2,352	0	24	2,093	235
95	7	1,451	0	15	1,291	145
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-38 Total Suspended Solids TMDL Calculations for Lower West Mud Creek (OK311100040080_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	10,057	NA	NA	NA	NA	NA
5	226	NA	NA	NA	NA	NA
10	63	NA	NA	NA	NA	NA
15	29	NA	NA	NA	NA	NA
20	18	NA	NA	NA	NA	NA
25	12	1,031	0	10	763	258
30	8	703	0	7	520	176
35	5	469	0	5	347	117
40	4	352	0	4	260	88
45	3	234	0	2	173	59
50	2	164	0	2	121	41
55	1	117	0	1	87	29
60	1	77	0	1	57	19
65	1	54	0	1	40	13
70	0	32	0	0	24	8
75	0	17	0	0	13	4
80	0	9	0	0	7	2
85	0	4	0	0	3	1
90	0	0	0	0	0	0
95	0	0	0	0	0	0
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-39 Total Suspended Solids TMDL Calculations for Mud Creek (OK311100040010_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	38,172	NA	NA	NA	NA	NA
5	857	NA	NA	NA	NA	NA
10	237	NA	NA	NA	NA	NA
15	110	NA	NA	NA	NA	NA
20	68	NA	NA	NA	NA	NA
25	44	7832	0	78	6970	783
30	30	5340	0	53	4753	534
35	20	3560	0	36	3168	356
40	15	2670	0	27	2376	267
45	10	1780	0	18	1584	178
50	7	1246	0	12	1109	125
55	5	890	0	9	792	89
60	3	534	0	5	475	53
65	2.3	409	0	4	364	41
70	2	356	0	4	317	36
75	2	356	0	4	317	36
80	2	356	0	4	317	36
85	2	356	0	4	317	36
90	2	356	0	4	317	36
95	2	356	0	4	317	36
100	2	356	0	4	317	36

NA = Not Applicable

Table 5-40 Total Suspended Solids TMDL Calculations for Fleetwood Creek (OK311100010300_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	1,810	NA	NA	NA	NA	NA
5	32	NA	NA	NA	NA	NA
10	17	NA	NA	NA	NA	NA
15	10	NA	NA	NA	NA	NA
20	7	NA	NA	NA	NA	NA
25	5	1,018	0	10	906	102
30	3	712	0	7	634	71
35	2	480	0	5	427	48
40	2	320	0	3	285	32
45	1	218	0	2	194	22
50	1	160	0	2	142	16
55	1	115	0	1	102	11
60	0	77	0	1	69	8
65	0	34	0	0	31	3
70	0	13	0	0	12	1
75	0	3	0	0	3	0
80	0	0	0	0	0	0
85	0	0	0	0	0	0
90	0	0	0	0	0	0
95	0	0	0	0	0	0
100	0	0	0	0	0	0

NA = Not Applicable

Table 5-41 Total Suspended Solids TMDL Calculations for Red Creek (OK311100010290_00)

Percentile	Flow (cfs)	TMDL (lb/day)	WLA (lb/day)		LA (lb/day)	MOS (lb/day)
			WWTP	Future growth		
0	14,368	NA	NA	NA	NA	NA
5	690	NA	NA	NA	NA	NA
10	343	NA	NA	NA	NA	NA
15	220	NA	NA	NA	NA	NA
20	149	NA	NA	NA	NA	NA
25	89	16,177	0	162	14,398	1,618
30	38	7,026	0	70	6,253	703
35	18	3,326	0	33	2,961	333
40	12	2,206	0	22	1,963	221
45	9	1,730	0	17	1,540	173
50	8	1,393	0	14	1,240	139
55	7	1,209	0	12	1,076	121
60	6	1,019	0	10	907	102
65	5	878	0	9	781	88
70	4	726	0	7	646	73
75	3	563	0	6	501	56
80	2	449	0	4	400	45
85	2	364	0	4	324	36
90	1	261	0	3	232	26
95	1	98	0	1	87	10
100	0	0	0	0	0	0

NA = Not Applicable

5.7 Reasonable Assurances

ODEQ will collaborate with a host of other state agencies and local governments working within the boundaries of state and local regulations to target available funding and technical assistance to support implementation of pollution controls and management measures. Various water quality management programs and funding sources provide reasonable assurance that the pollutant reductions as required by these TMDLs can be achieved and water quality can be restored to maintain designated uses. ODEQ's Continuing Planning Process (CPP), required by the CWA §303(e)(3) and 40 CFR 130.5, summarizes Oklahoma's commitments and programs aimed at restoring and protecting water quality throughout the State (ODEQ 2006). The CPP can be viewed from ODEQ's website at http://www.deq.state.ok.us/WQDnew/pubs.html Table 5-42 provides a partial list of the state partner agencies ODEQ will collaborate with to address point and nonpoint source reduction goals established by TMDLs.

Table 5-42 Partial List of Oklahoma Water Quality Management Agencies

Agency	Web Link
Oklahoma Conservation Commission	http://www.ok.gov/conservation/Agency_Divisions/Water_Quality_Division
Oklahoma Department of Wildlife Conservation	http://www.wildlifedepartment.com/watchabl.htm
Oklahoma Department of Agriculture, Food, and Forestry	http://www.ok.gov/~okag/aems
Oklahoma Water Resources Board	http://www.owrb.state.ok.us/quality/index.php

Nonpoint source pollution in Oklahoma is managed by the Oklahoma Conservation Commission. The Oklahoma Conservation Commission works with state partners such as ODAFF and federal partners such as the USEPA and the National Resources Conservation Service of the U.S. Department of Agriculture, to address water quality problems similar to those seen in the Study Area. The primary mechanisms used for management of nonpoint source pollution are incentive-based programs that support the installation of BMPs and public education and outreach. Other programs include regulations and permits for CAFOs. The CAFO Act, as administered by the ODAFF, provides CAFO operators the necessary tools and information to deal with the manure and wastewater animals produce so streams, lakes, ponds, and groundwater sources are not polluted.

As authorized by Section 402 of the CWA, the ODEQ has delegation of the NPDES Program in Oklahoma, except for certain jurisdictional areas related to agriculture and the oil and gas industry retained by State Department of Agriculture and Oklahoma Corporation Commission, for which the USEPA has retained permitting authority. The NPDES Program in Oklahoma is implemented via Title 252, Chapter 606 of the Oklahoma Pollution Discharge Elimination System (OPDES) Act and in accordance with the agreement between ODEQ and USEPA relating to administration and enforcement of the delegated NPDES Program. Implementation of point source WLAs is done through permits issued under the OPDES program.

The reduction rates called for in this TMDL report are as high as 99 percent. The ODEQ recognizes that achieving such high reductions will be a challenge, especially since unregulated nonpoint sources are a major cause of both bacteria and TSS loading. The high reduction rates are not uncommon for pathogen- or TSS-impaired waters. Similar reduction rates are often found in other pathogen and TSS TMDLs around the nation. The suitability of the current criteria for pathogens and the beneficial uses of a waterbody should be reviewed. For example, the Kansas Department of Environmental Quality has proposed to exclude certain high flow conditions during which pathogen standards will not apply, although that exclusion was not approved by the USEPA. Additionally, USEPA has been conducting new epidemiology studies and may develop new recommendations for pathogen criteria in the near future.

Revisions to the current pathogen provisions of Oklahoma's WQSs should be considered. There are three basic approaches to such revisions that may apply.

Removing the PBCR use: This revision would require documentation in a Use Attainability Analysis that the use is not an existing use and cannot be attained. It is unlikely that this approach would be successful since there is evidence that people do swim in this segment of the river, thus constituting an existing use. Existing uses cannot be removed.

Modifying application of the existing criteria: This approach would include considerations such as an exemption under certain high flow conditions, an allowance for wildlife or "natural conditions," a sub-category of the use or other special provision for urban areas, or other special provisions for storm flows. Since large bacteria violations occur over all flow ranges, it is likely that large reductions would still be necessary. However, this approach may have merit and should be considered.

Revising the existing numeric criteria: Oklahoma's current pathogen criteria are based on USEPA guidelines (See Implementation Guidance for Ambient Water Quality Criteria for Bacteria, May 2002 Draft; and Ambient Water Quality Criteria for Bacteria-1986, January 1986). However, those guidelines have received much criticism and USEPA studies that could result in revisions to their recommendations are ongoing. The use of the three indicators specified in Oklahoma's standards should be evaluated. The numeric criteria values should also be evaluated using a risk-based method such as that found in USEPA guidance.

Unless or until the WQSs are revised and approved by USEPA, federal rules require that the TMDLs in this report must be based on attainment of the current standards. If revisions to the pathogen standards are approved in the future, reductions specified in these TMDLs will be re-evaluated.

SECTION 6
PUBLIC PARTICIPATION

This report was submitted to EPA for technical review on June 29, 2010 and was technicaly accepted on July 14, 2010. A public notice was circulated on July 16, 2010 to local newspapers and/or other publications in the area affected by this TMDL and persons on the DEQ contact list. The public comment period ended on August 31, 2010. No requests for a public meeting were received. One comment letter from Oklahoma Farm Bureau was received. The responses to comments are included in Appendix E. as part of this TMDL report.

SECTION 7
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